Health Effects & Characterization of Urban and Rural $PM_{10-2.5}$ in NE Colorado

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UWisc – J. Schauer

UWash – S. Vedal

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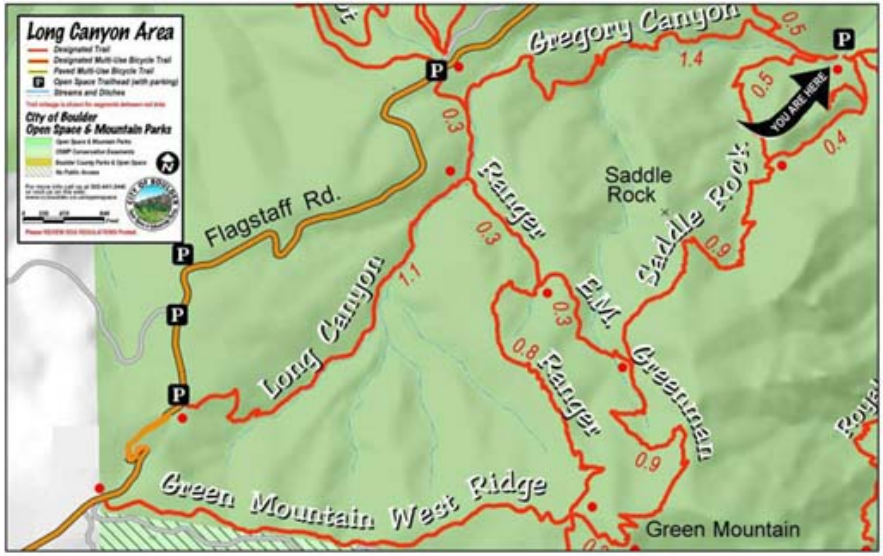
Not Pictured: Josh Hemann, Allison Moore

CRUSH

our rural & urban ecosystems

Trail Map



I. What are we doing?

II. Continuous PM measurements
   - Challenges (O & M, Data processing)
   - Results

III. Filter sampling
   - Mass
   - Carbonaceous

IV. Near Term Plans

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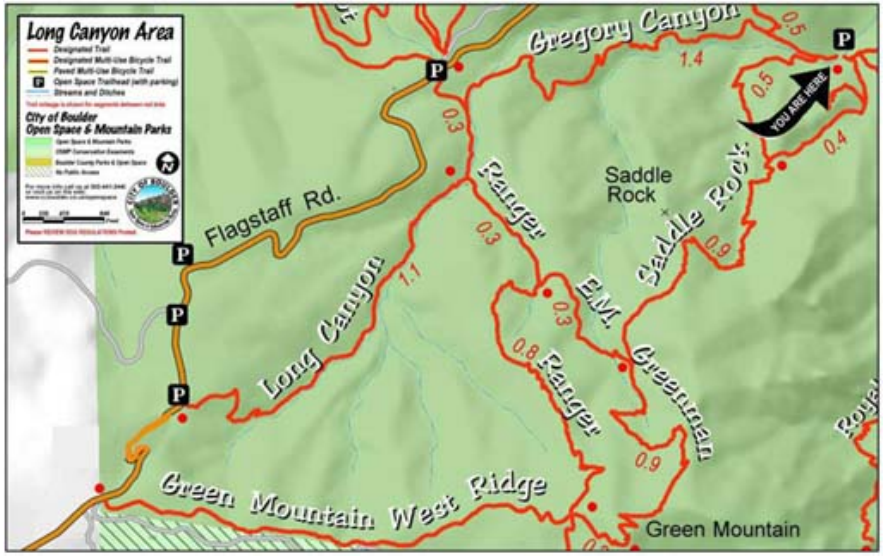

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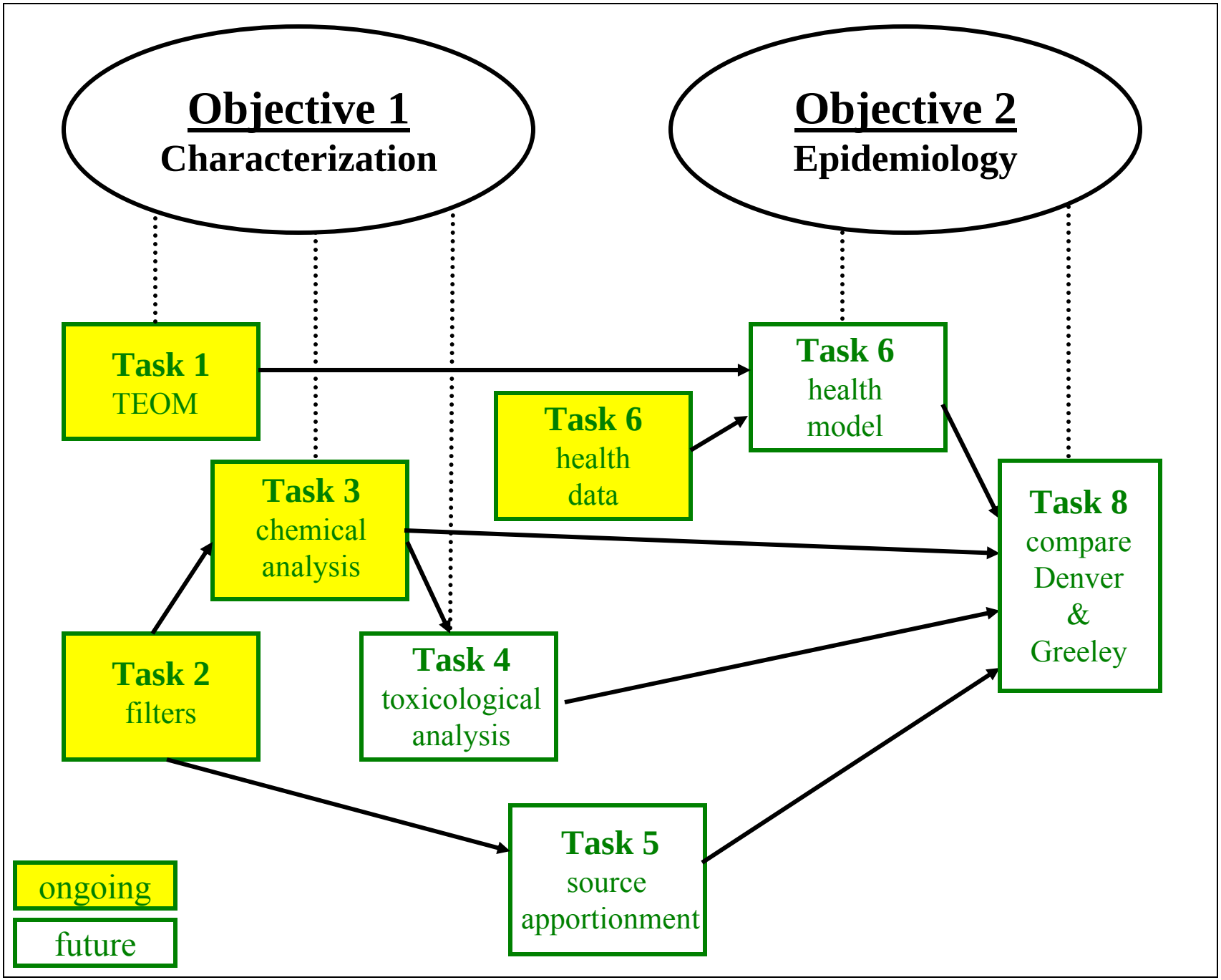
What are we doing?

Objective 1 (Characterization)

Characterize $PM_{10-2.5}$ mass, composition, toxicity, and origin in Denver and Greeley

Objective 2 (Health Effects)

Evaluate the association of $PM_{10-2.5}$ mass and several health outcomes in Denver & Greeley


Objective 1
Characterization
Objective 2
Epidemiology
Task 1
TEOM
Task 6
health
model
Task 6
health
data
Task 3
chemical
analysis
Task 8
compare
Denver
&
Greeley
Task 2
filters
Task 4
toxicological
analysis
Task 5
source
apportionment
ongoing
future

Resultant Data

$PM_{10-2.5}$ Characterization

1. Mass

3 years

2. Ions (IC)
3. Bulk carbon (NIOSH 5040)
4. Water soluble C & N
5. Trace metals
6. Endotoxin
7. Total carbohydrates
8. Total proteins
9. Macrophage assays

   ROS production & cytotoxicity

Health Endpoints

1. Arrhythmic events

   ICD patients
2. Respiratory ED visits
3. Cardiovascular ED visits
4. Preterm births
5. Intrauterine growth retardation

Filter measurements (250)

Resulting Data Analysis

Models to be evaluated

1. Source apportionment
2. Exposure assignment
3. Health outcome

Urban/Rural Comparison

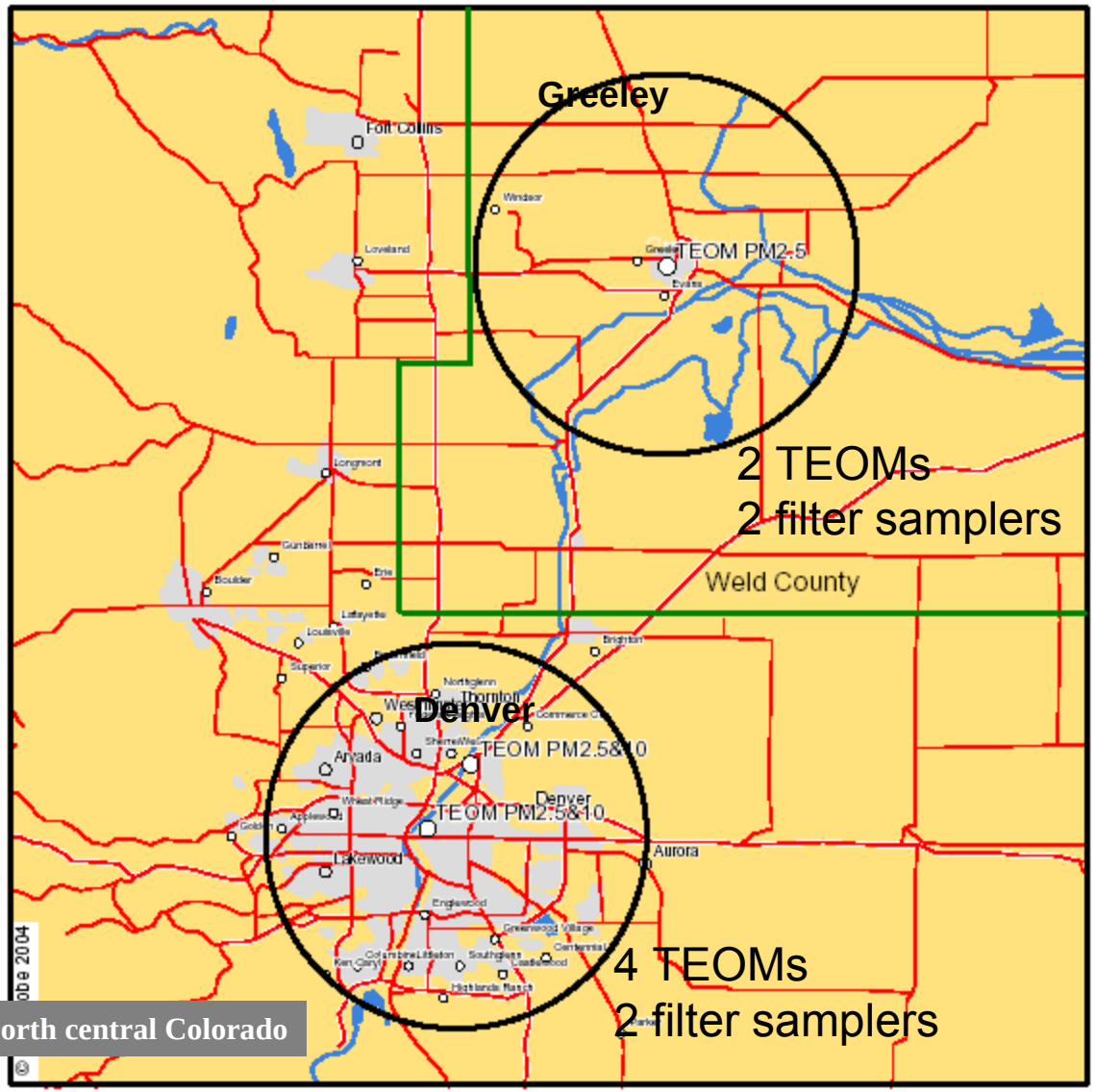
1. Mass
2. Ions
3. Bulk carbon
4. Water soluble C & N
5. Trace metals
6. Endotoxin
7. Total carbohydrates
8. Total proteins
9. Macrophage bioassays
10. **Sources**

60 sets
set = 2 Greeley vs 2 Denver

PLUS,
DNA sequence
(bacterial ecology)

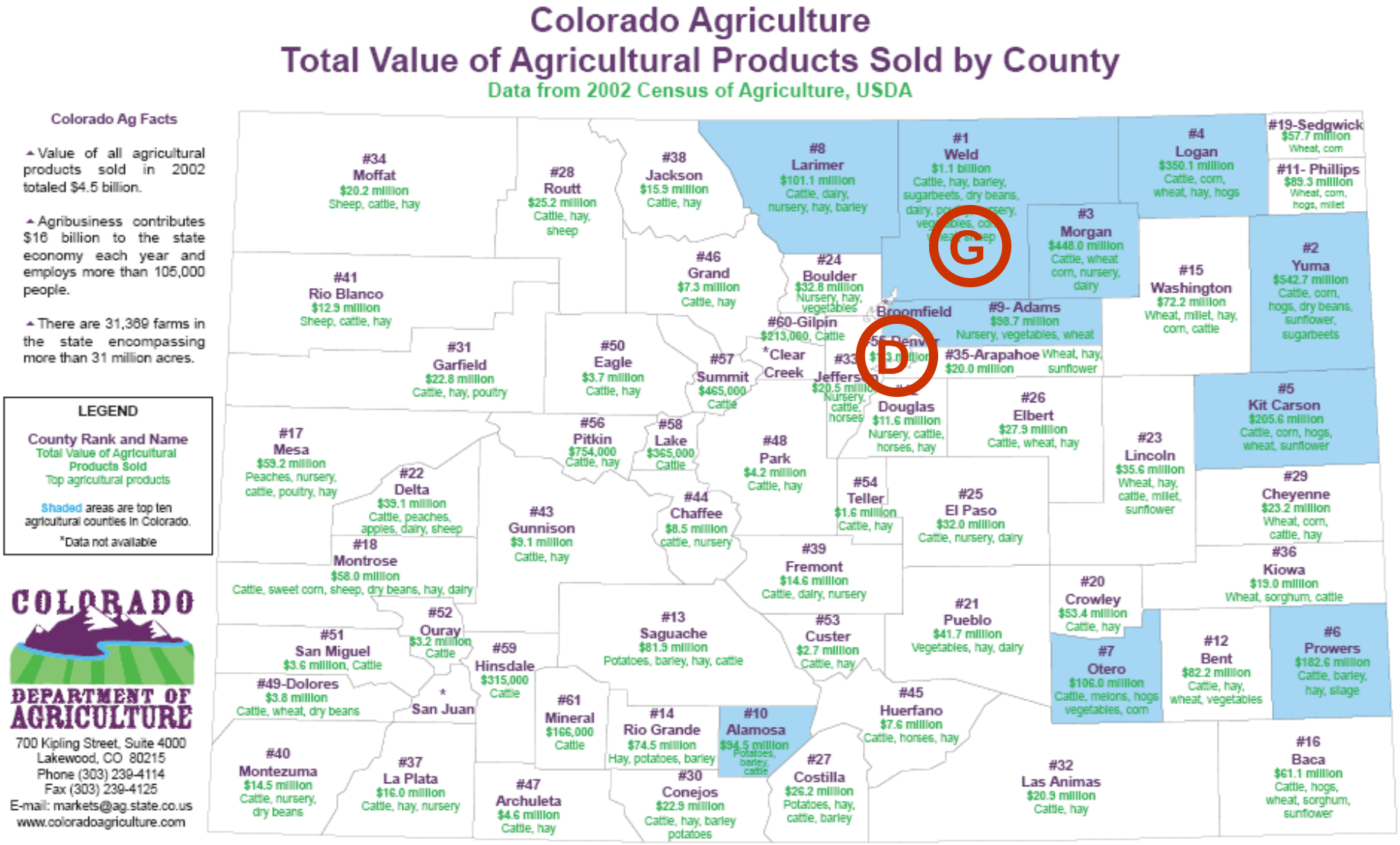
11. **$PM_{10-2.5}$ mass effect estimate**

Our Lab
Urban – Rural Comparison

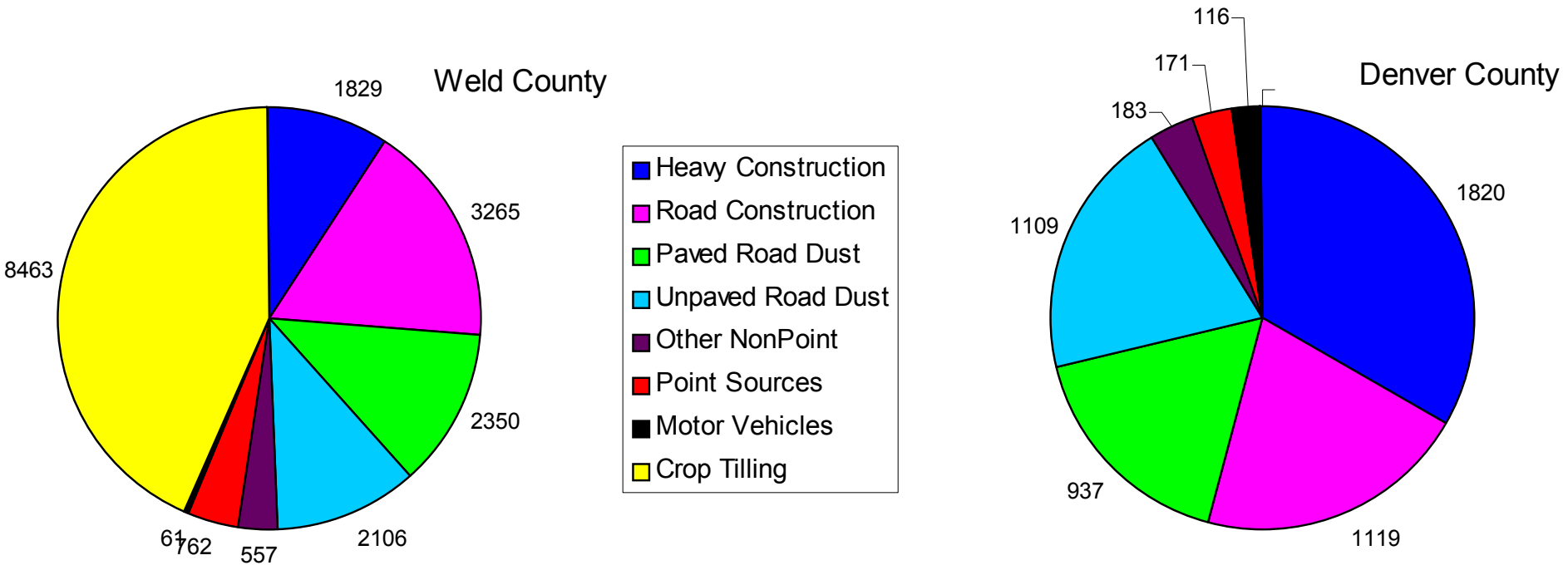


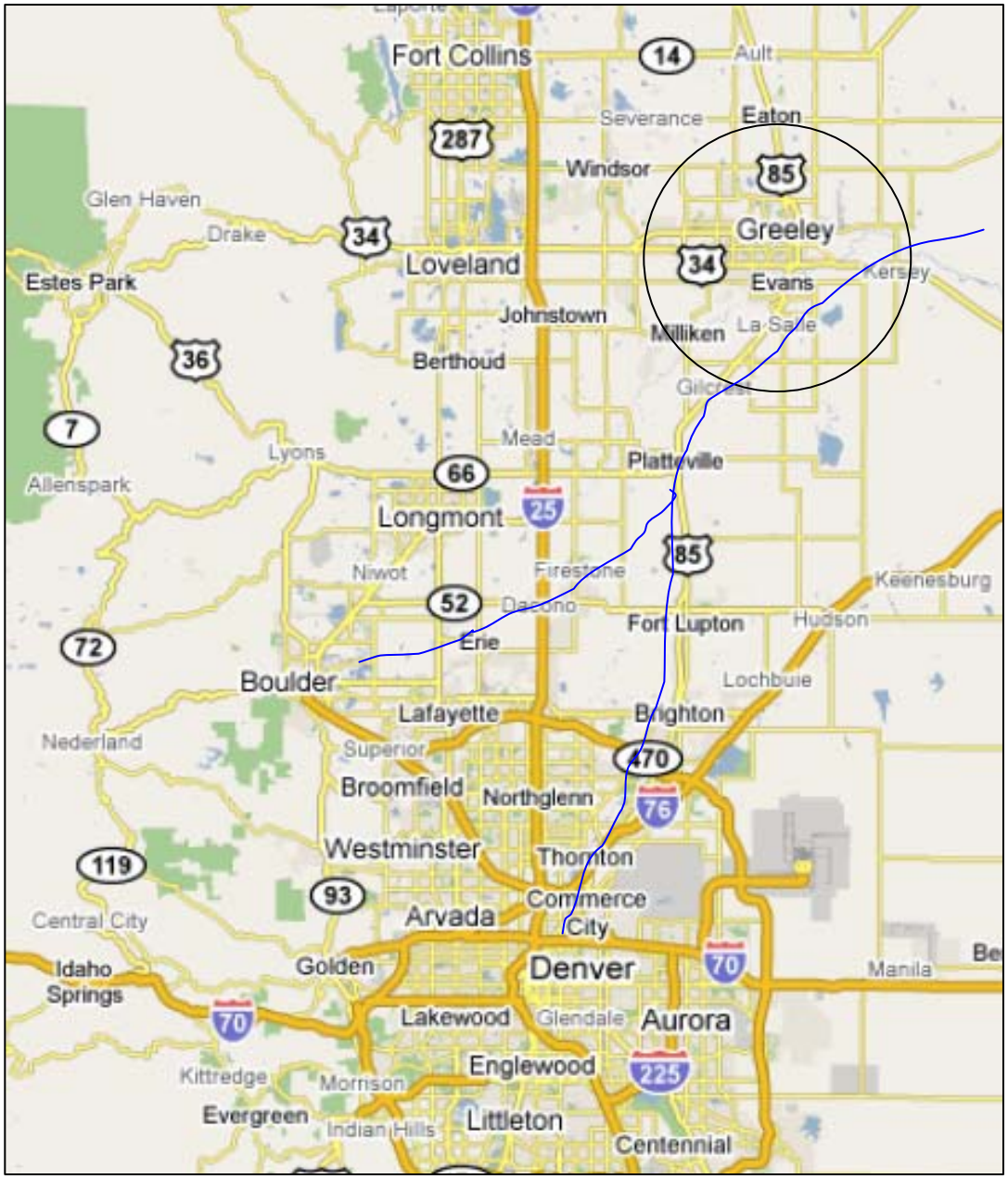
Map of study areas in north central Colorado

Greeley is the Weld County seat.
Weld County is the #1 agricultural county in Colorado and #8 in the US.
Ranks 2nd in the US in cattle and sheep inventory & sales ($ 0.9 billion)



$PM_{10-2.5}$ Emissions Inventory



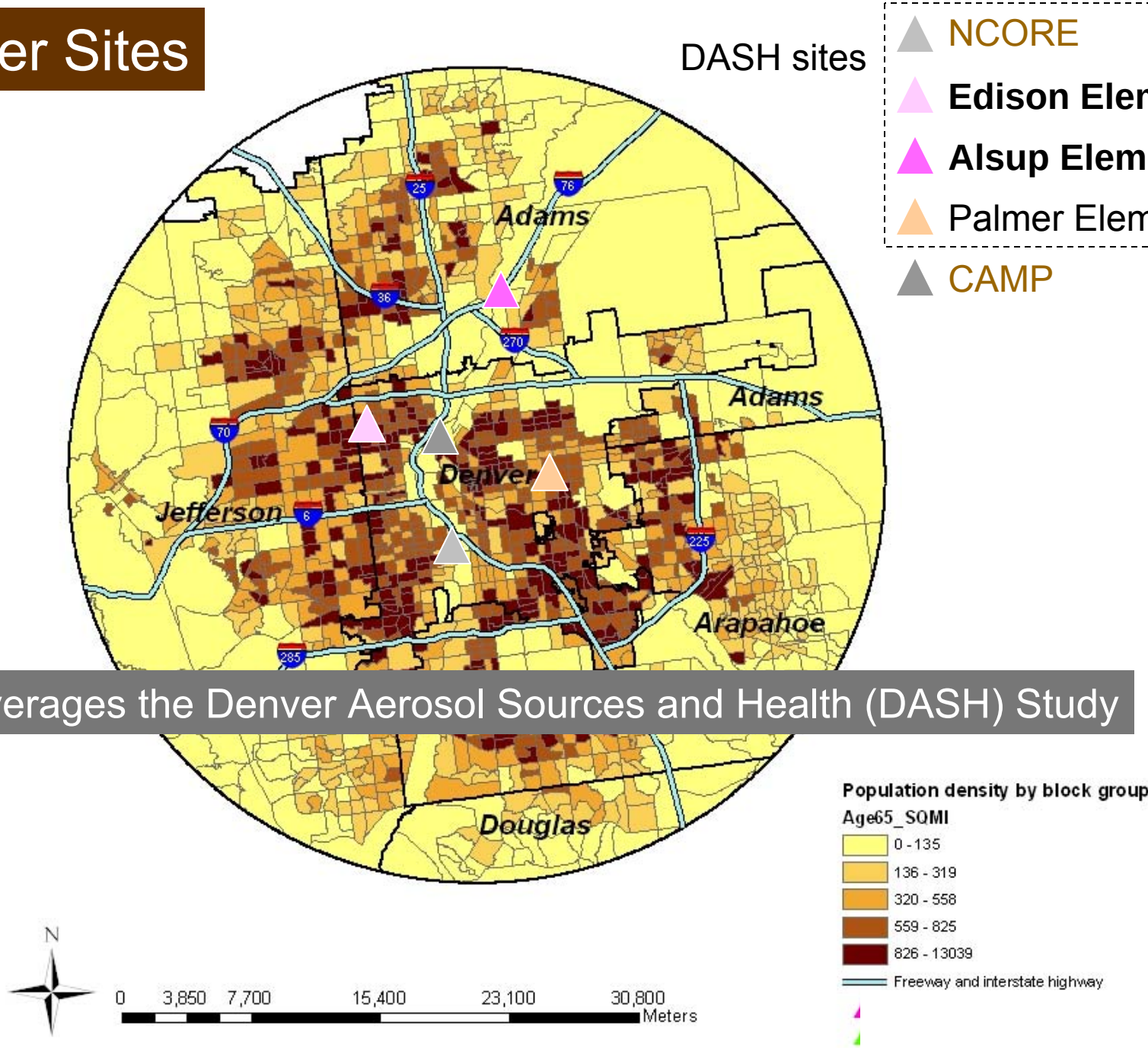


Greeley to Denver = 50 miles

<u>Greeley demographics:</u>
Population (2005): 88,249
Pop. change: +14.7% since 2000
Median income: $36,400
Pop. ≥ 65 yrs old: 10%
African American: < 1%
Hispanic: 29.5%

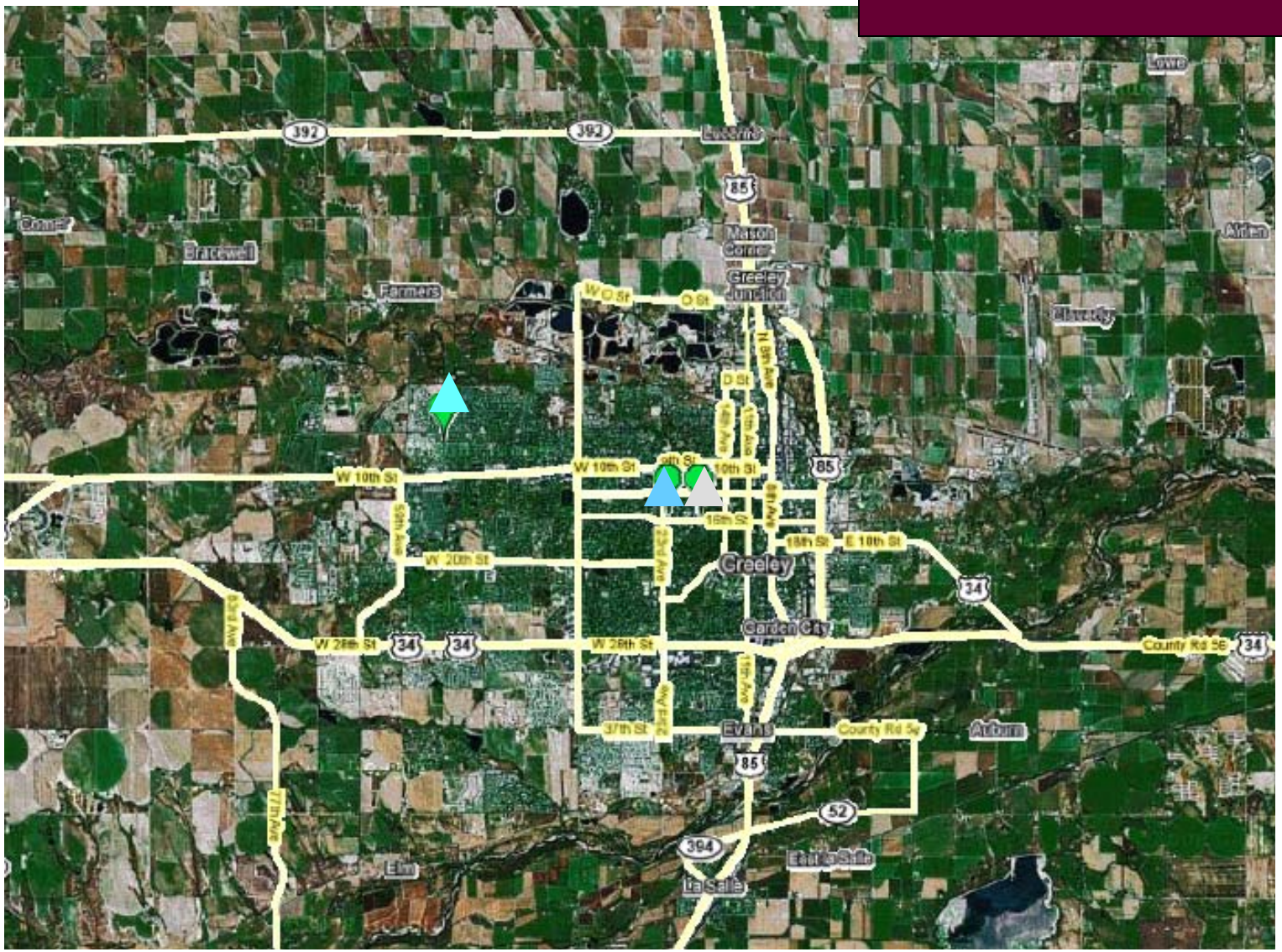
<u>Denver demographics:</u>
Population (2005): 557,917
Metro area pop.: 2.2 million
Median income: $39,500
Pop. ≥ 65 yrs old: 11%
African American: 11%
Hispanic: 32%

Denver Sites



Greeley Sites

- McAuliffe Elementary
- Maplewood Middle
- Greeley Hospital



Google Map

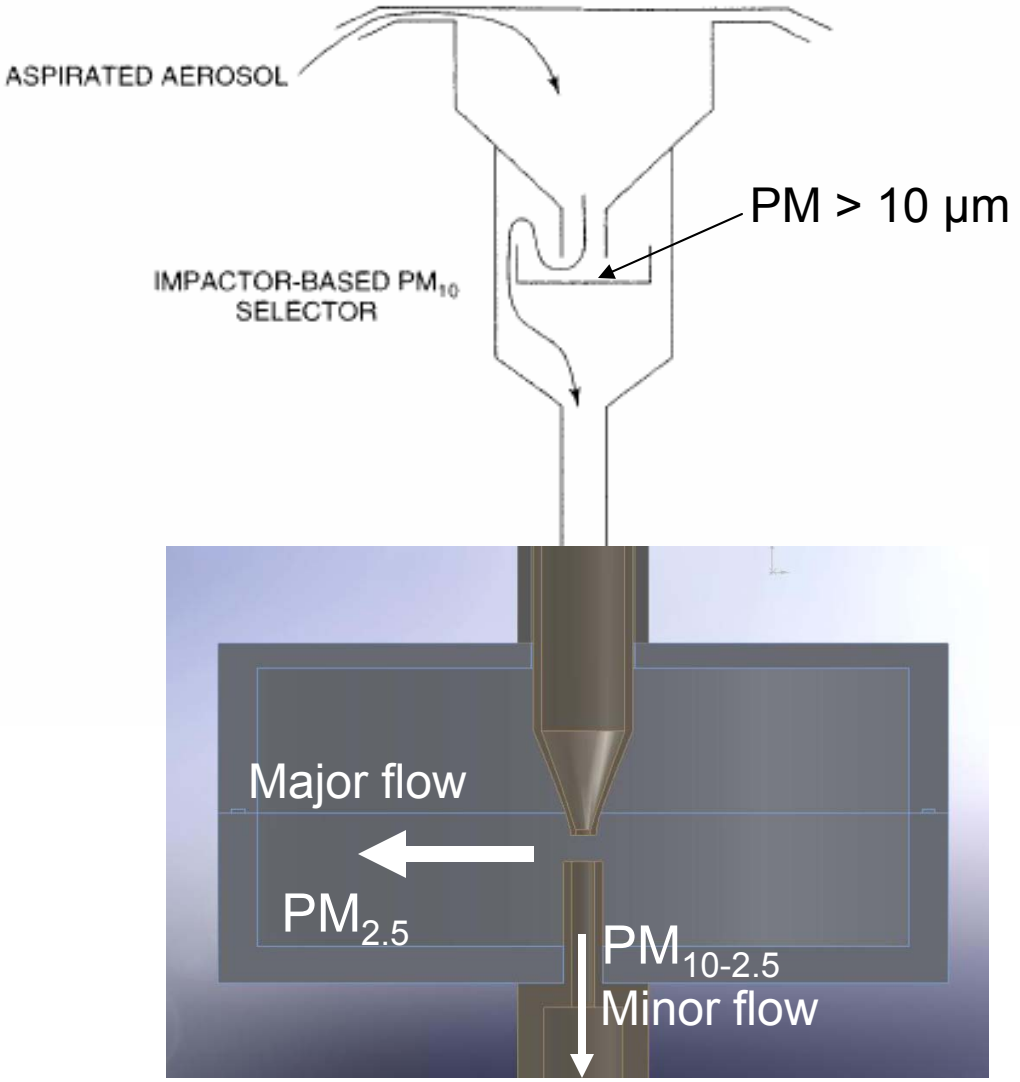
Monitoring/Collection Tools

TEOM 1405-DF

Mass Monitoring

Filter Collection

Size Separation



Impactor plus Virtual Impactor

Virtual Impactor Mass Correction

$$M_{PM2.5,TEOM} = \frac{V_{PM2.5}}{V_{PM10}} M_{PM2.5,TRUE}$$

$$M_{PM10-2.5,TEOM} = \frac{V_{PM10-2.5}}{V_{PM10}} M_{PM2.5,TRUE} + M_{PM10-2.5,TRUE}$$

$$V_{PM10} = V_{PM2.5} + V_{PM10-2.5}$$

$$M_{Calc} = M_{Base} - M_{Ref}$$

M = mass concentration (µg/m3)
V = volumetric flow rate (lpm)

Virtual impactors use particle inertia to separate size fractions

TEOM VI's designed with a cut point at ~2.5 µm

Flow rates dictate particle separation efficiency, the ratio of $PM_{10-2.5}$ to PM_{10} flow rates represents the proportion of $PM_{2.5}$ mass that enters the $PM_{10-2.5}$ collection nozzle

TRUE mass concentration of each channel (base and reference) calculated for each 6-minute interval

Flow rate concentration enrichment factor introduced before 'raw' data is reported (don't need to include)

'Calc', or volatile loss corrected, then calculated using the TRUE base and reference values

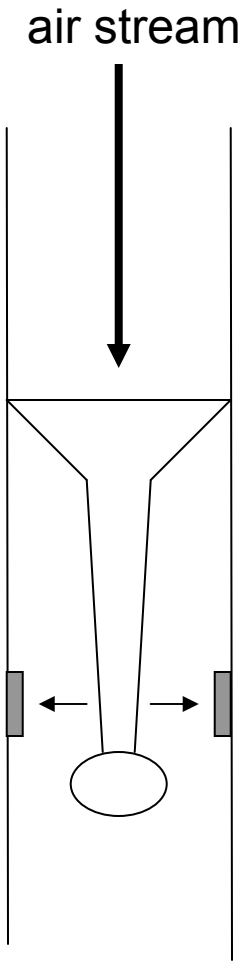
*This assumes the proportion of **volatile mass loss** is directly related to the **mass of the particles in each channel**, and the effect of $PM_{2.5}$ volatile mass loss occurring in the $PM_{10-2.5}$ channel can be removed with the same equation used for $PM_{2.5TRUE}$*

These calculations pose an interesting problem because Base and Reference channels measure values with different population distributions…

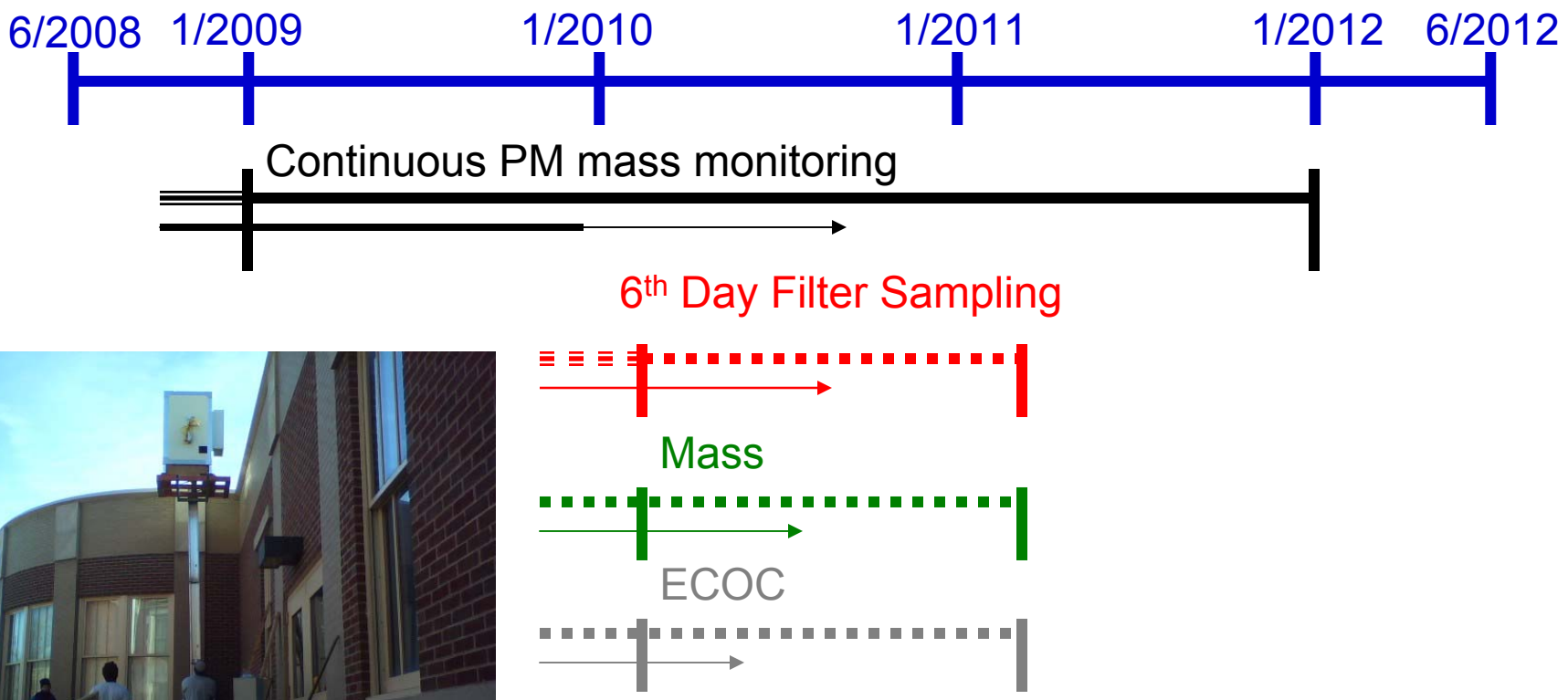
And FDMS corrections too.

TEOM
tapered element oscillating microbalance

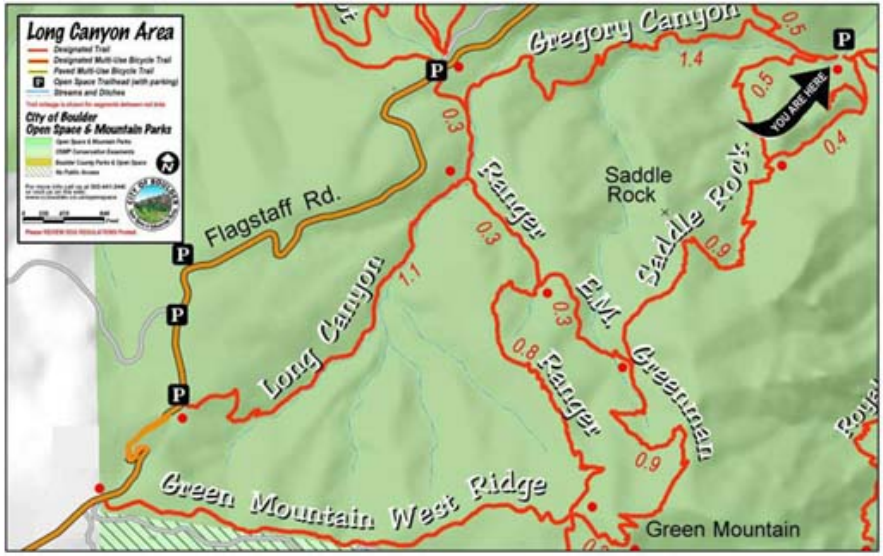
Frequency of oscillation changes based on mass



Progress


6/2008
1/2009
1/2010
1/2011
1/2012
6/2012
Continuous PM mass monitoring
6th Day Filter Sampling
Mass
ECOC

Trail Map



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Mass

Carbonaceous

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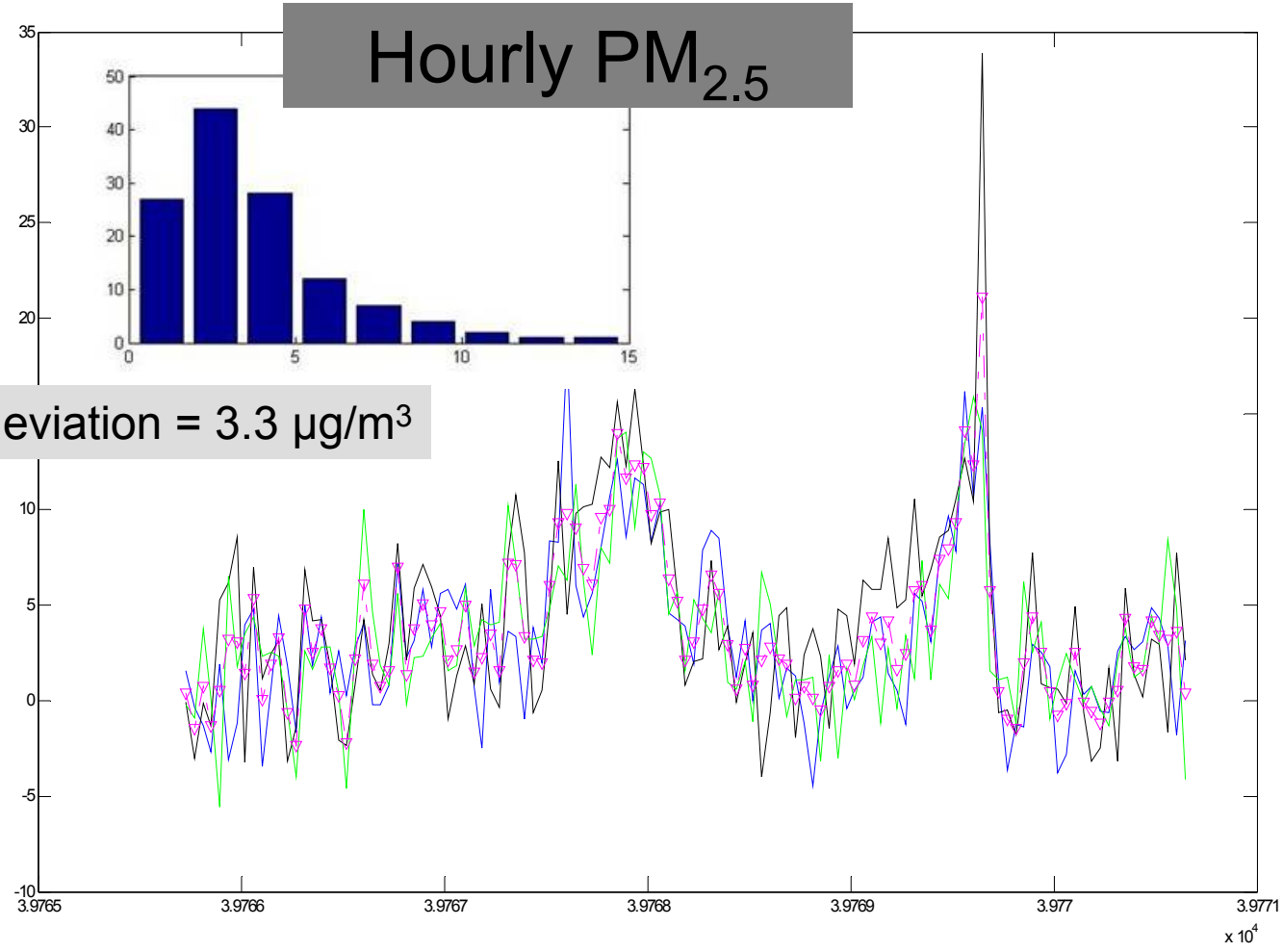
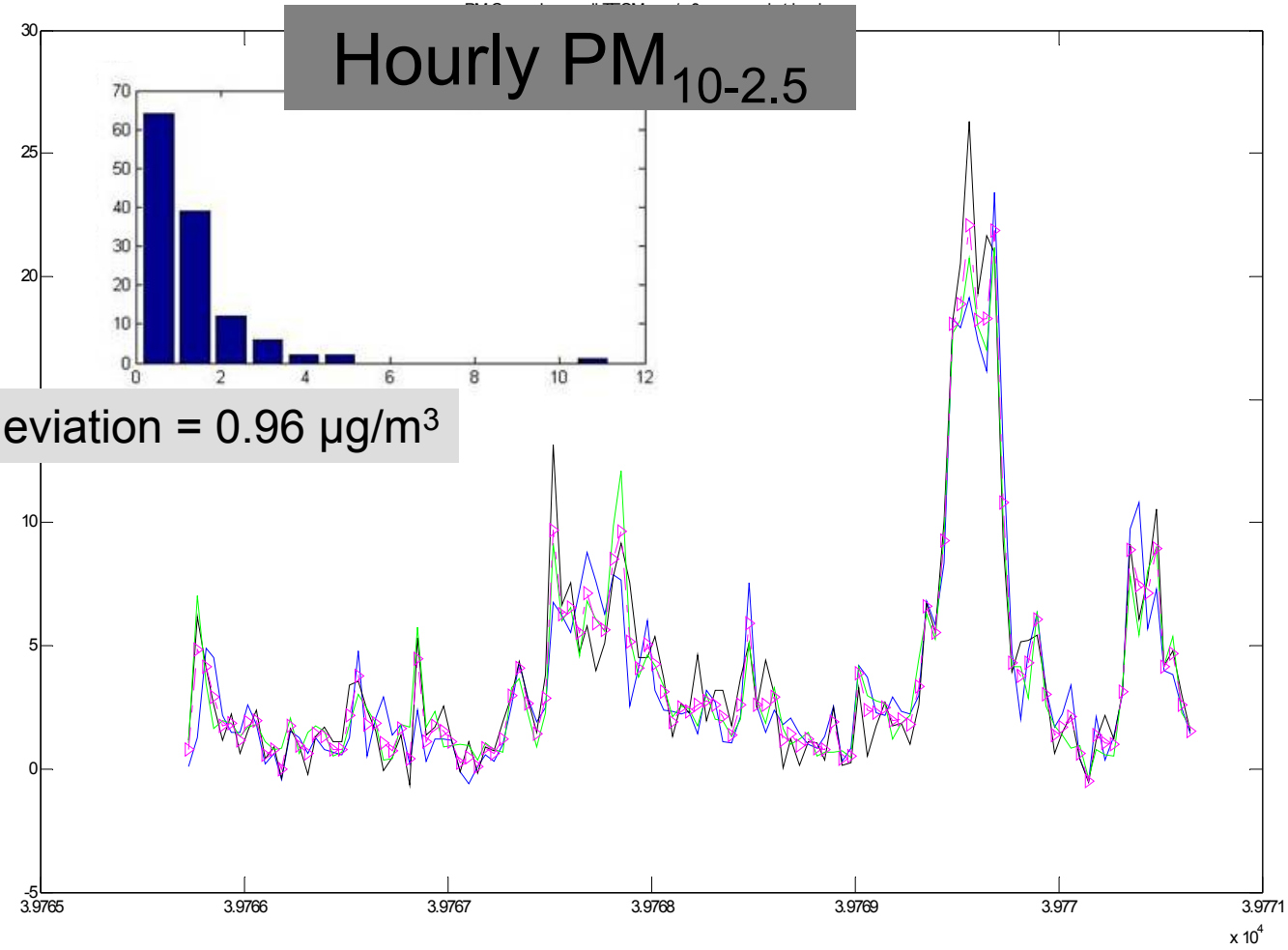
TEOM Side-by-Side Uncertainty Assessment



Median standard deviation = 3.3 µg/m^3

Ran three instruments at the same site to explore inherent variability in measurement.

TEOM Side-by-Side Uncertainty Assessment



Median standard deviation = 0.96 µg/m^3

Ran three instruments at the same site to explore inherent variability in measurement.

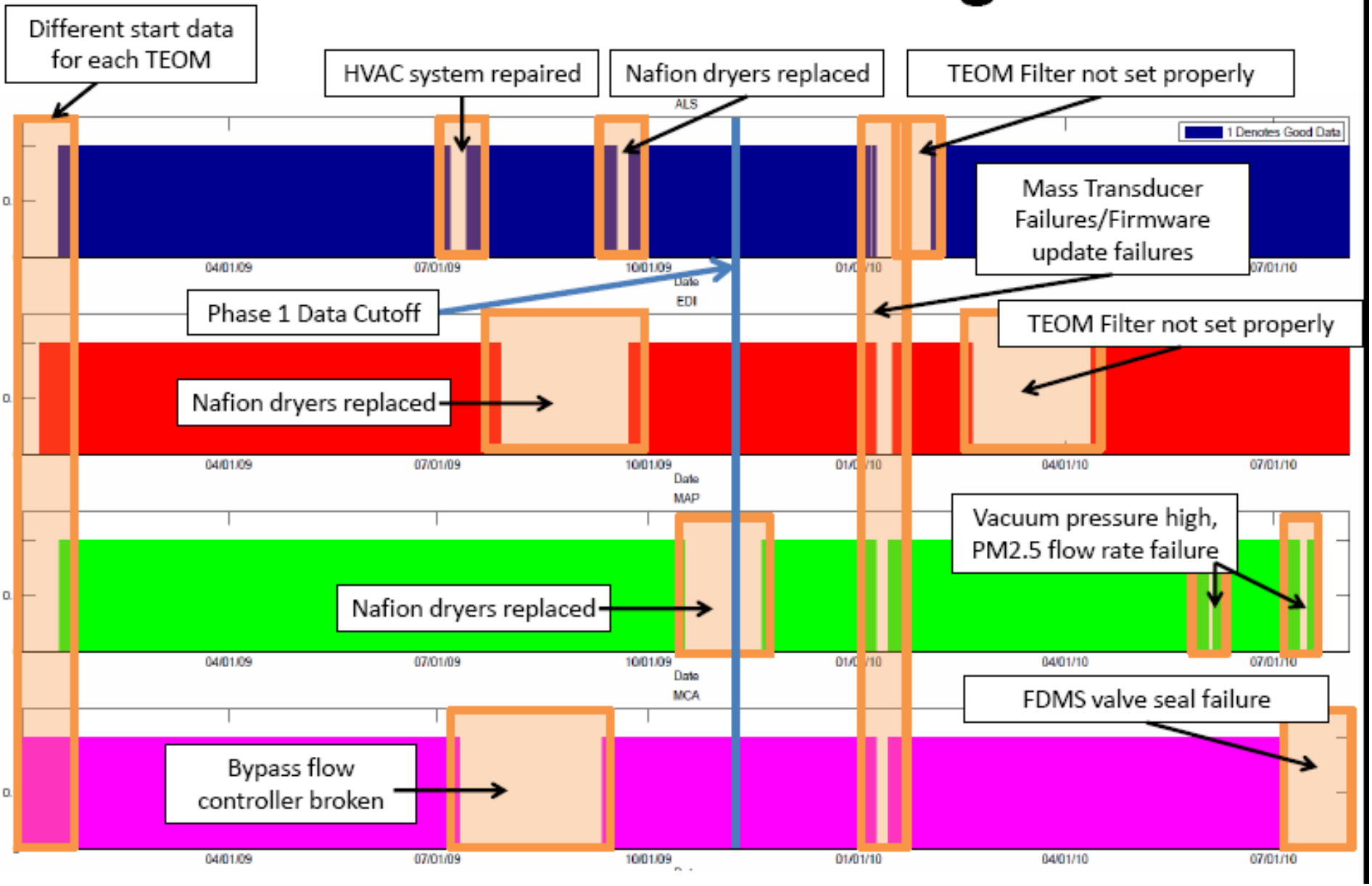
O & M Challenges

Uncle's advise that is ringing in my ears …

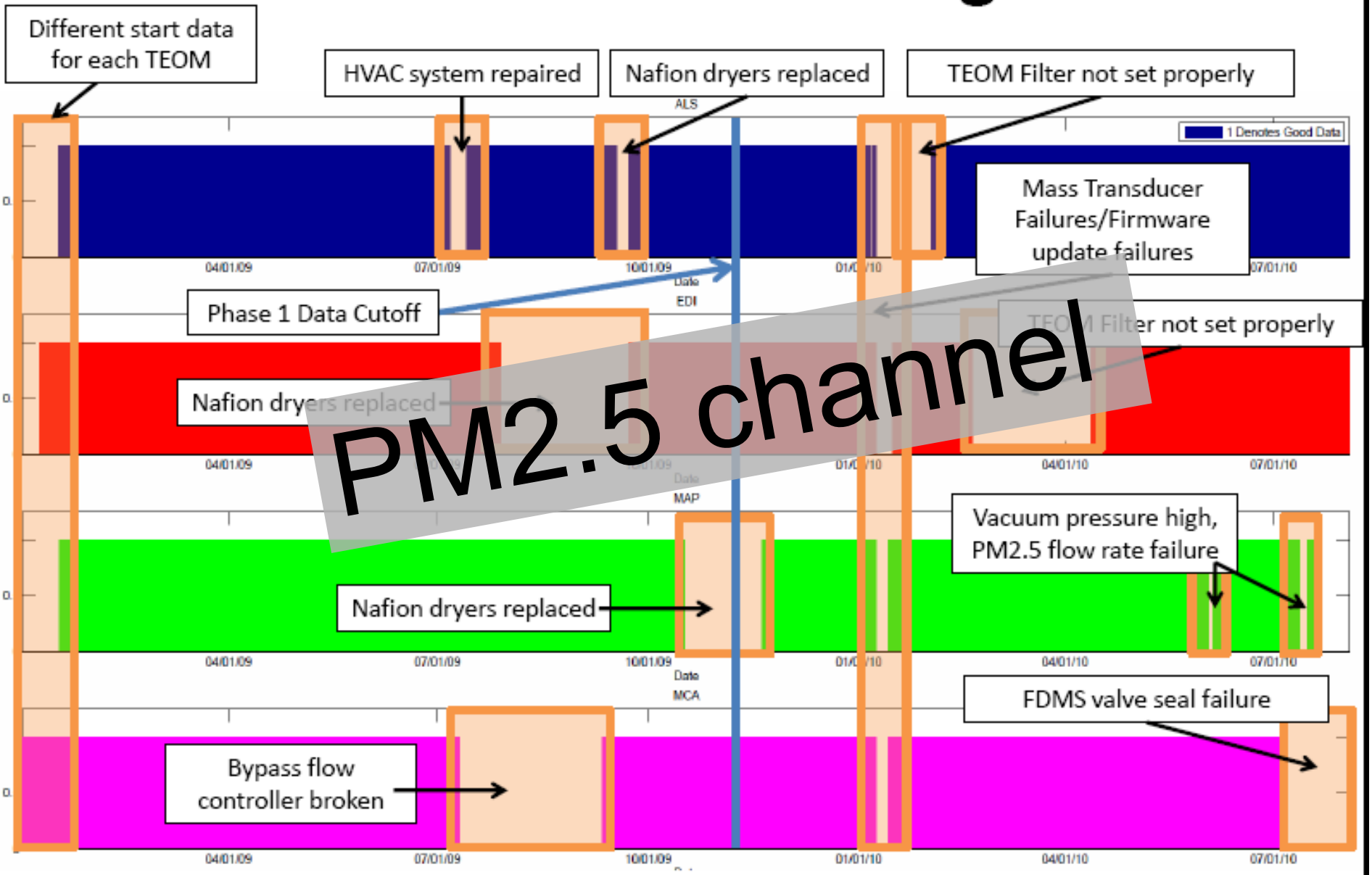
"Never buy the first mode year of a car"

- Operations
  - Three firmware updates so far
  - Visit sites frequently!
  - Measure flow more frequently than you want
  - Flow control and temperature control, arghhh.
- Maintenance
  - Driers, pumps and seals fail more frequently than you have money for.

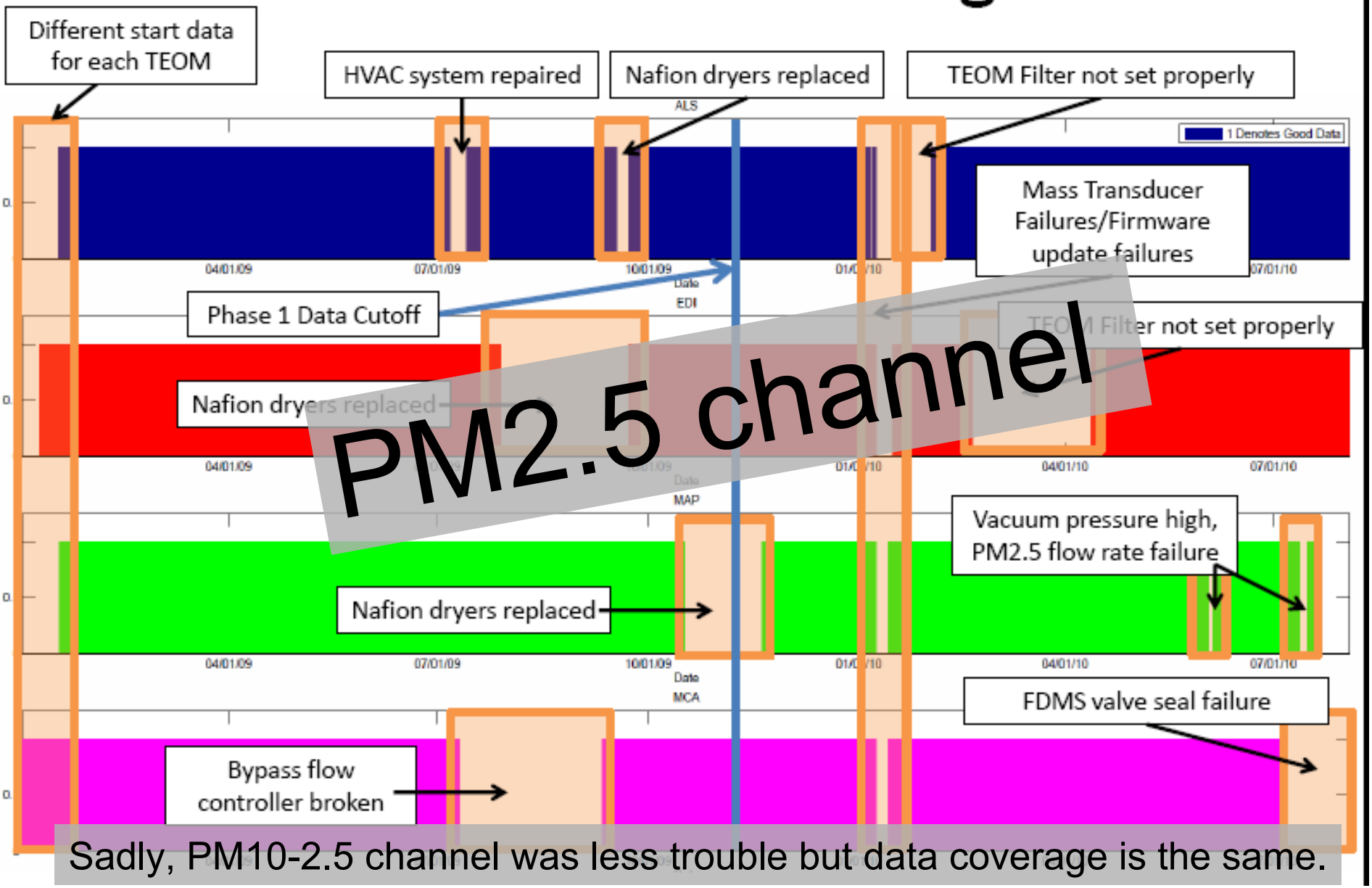
TEOM Data Coverage



TEOM Data Coverage

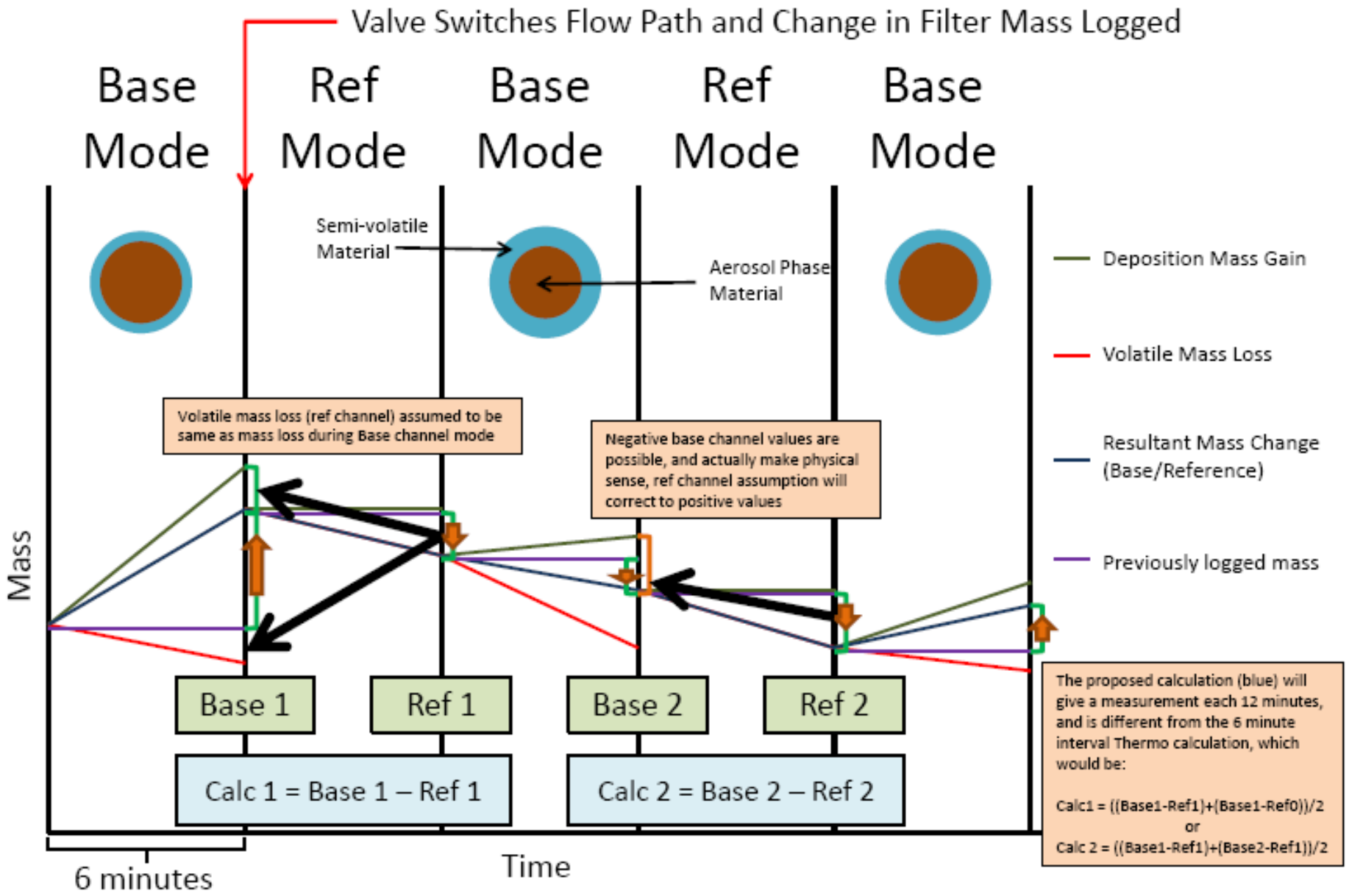


TEOM Data Coverage

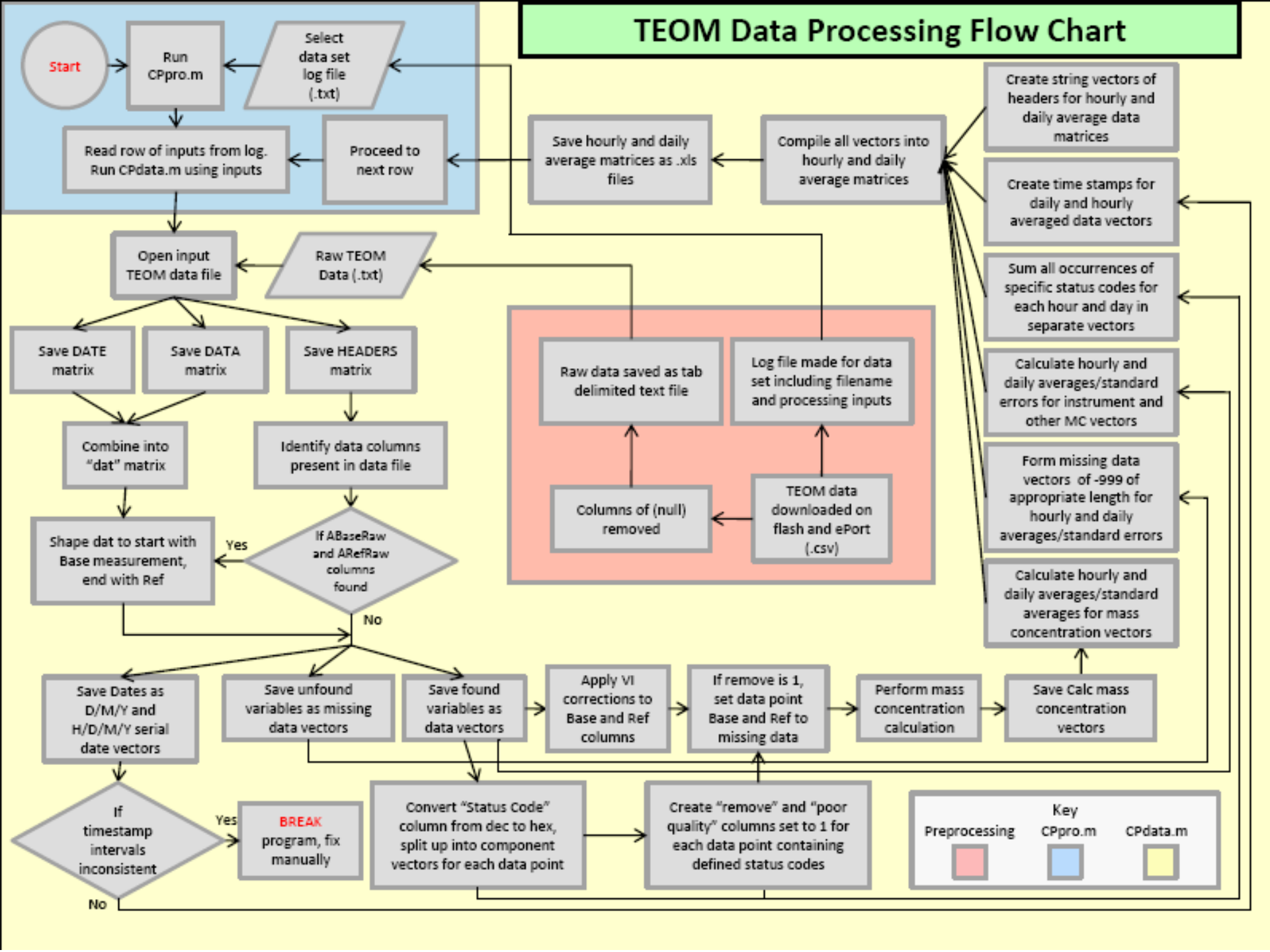


Sadly, PM10-2.5 channel was less trouble but data coverage is the same.

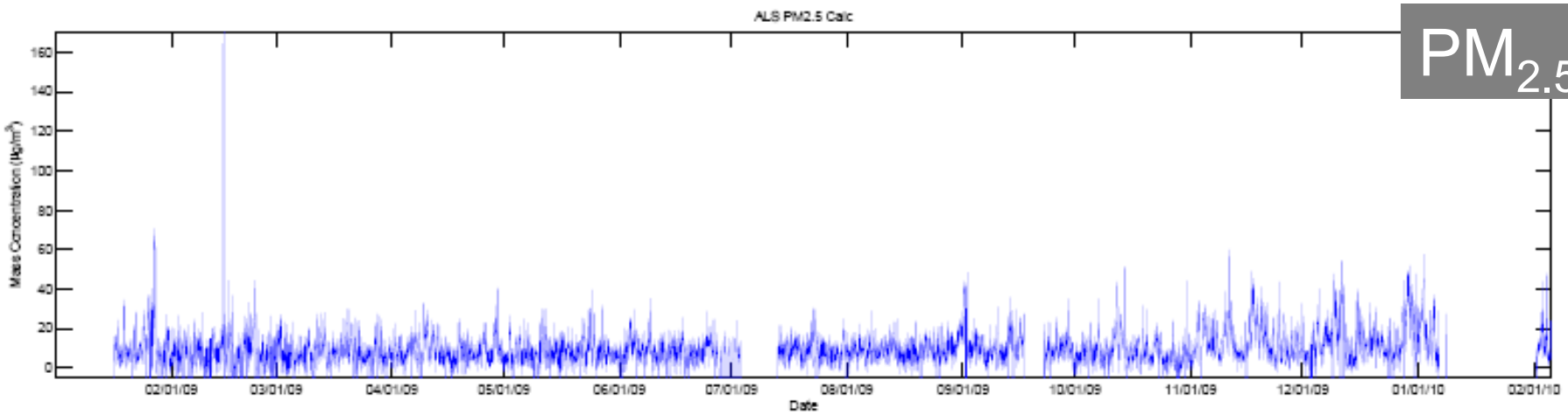
Mass Concentration Calculation



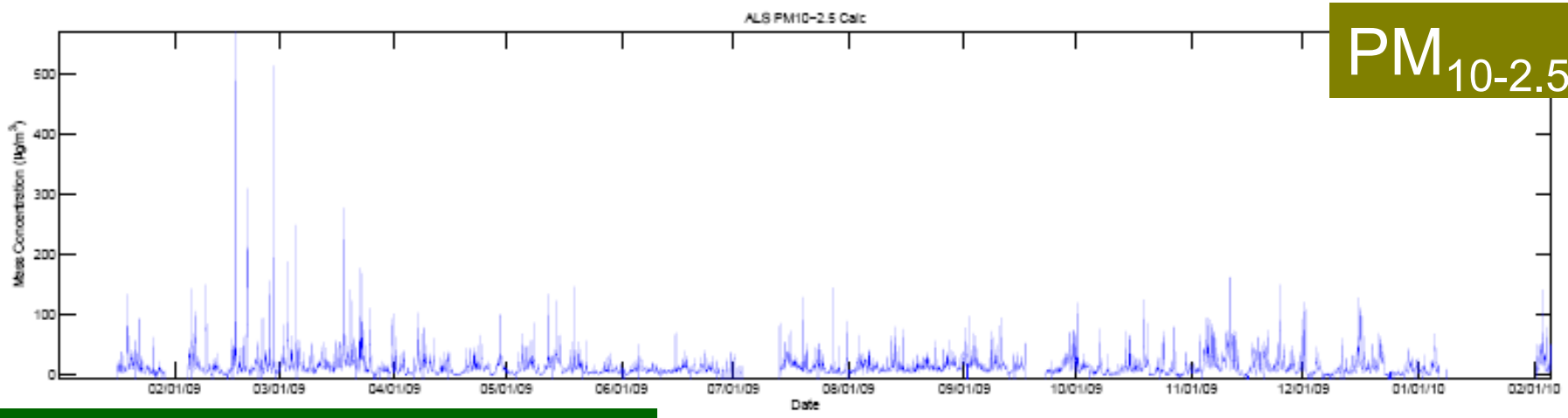
TEOM Data Processing Flow Chart



Time Series (hourly)



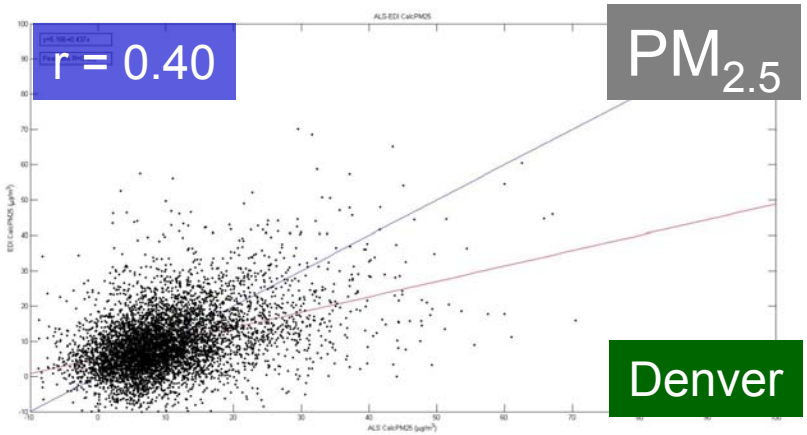
$PM_{2.5}$

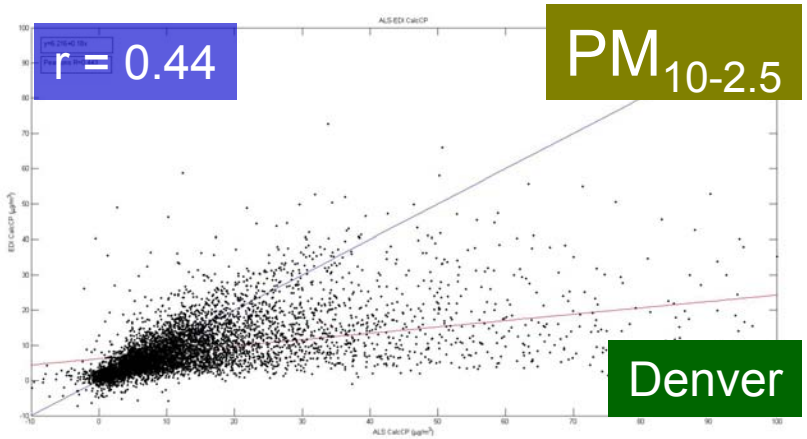


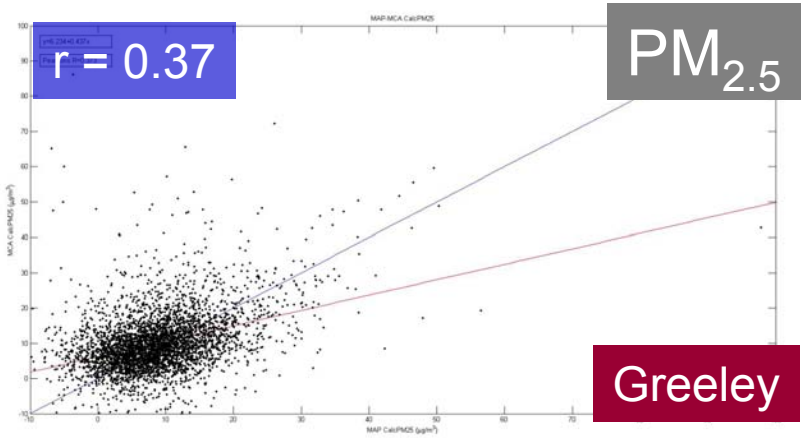
$PM_{10-2.5}$

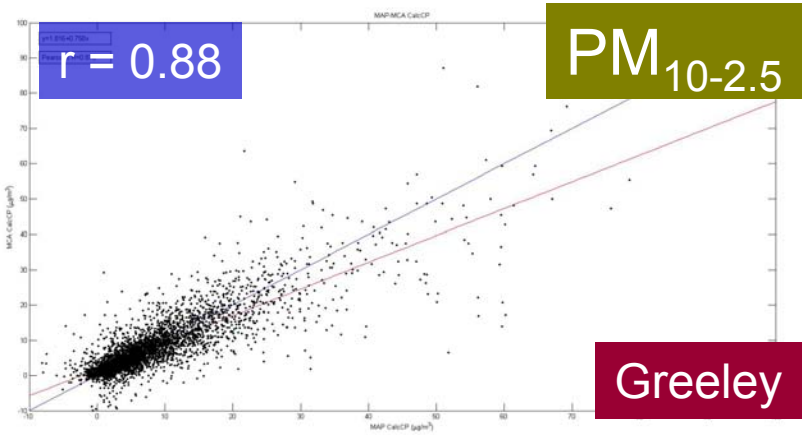
Alsup Elementary, Denver CSN site

Spatial Variability (hourly)

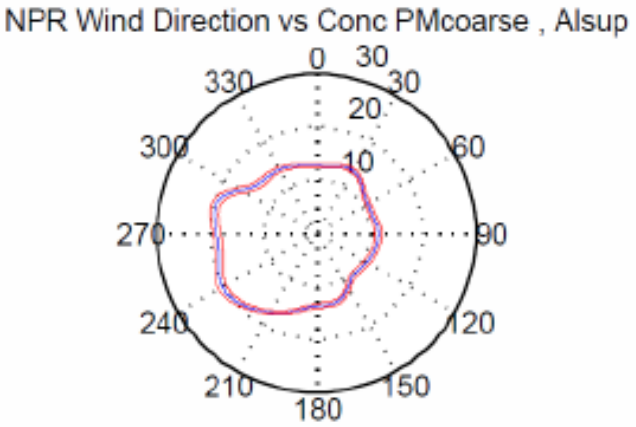


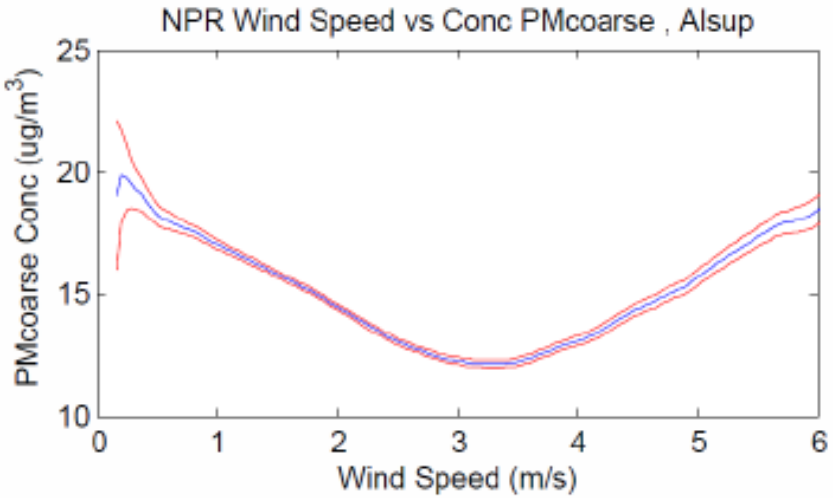




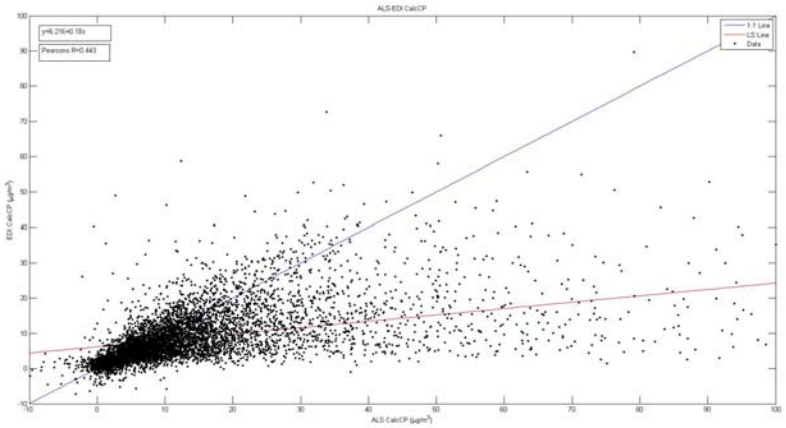


Denver $PM_{10-2.5}$

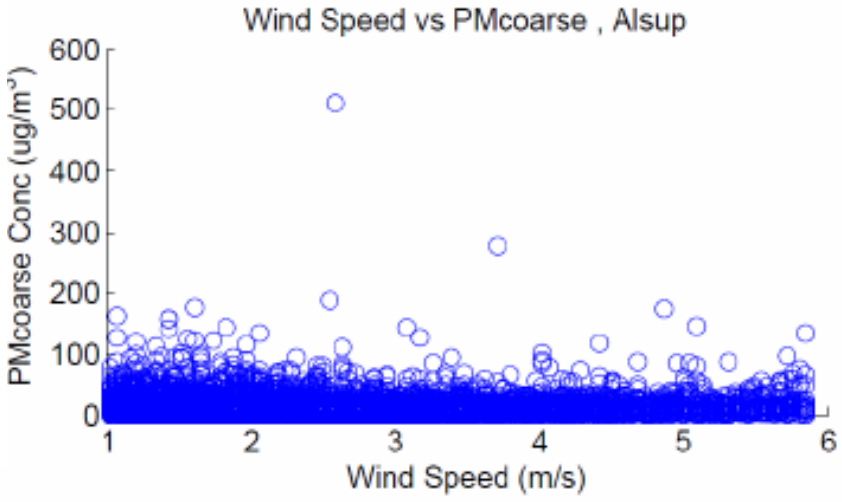




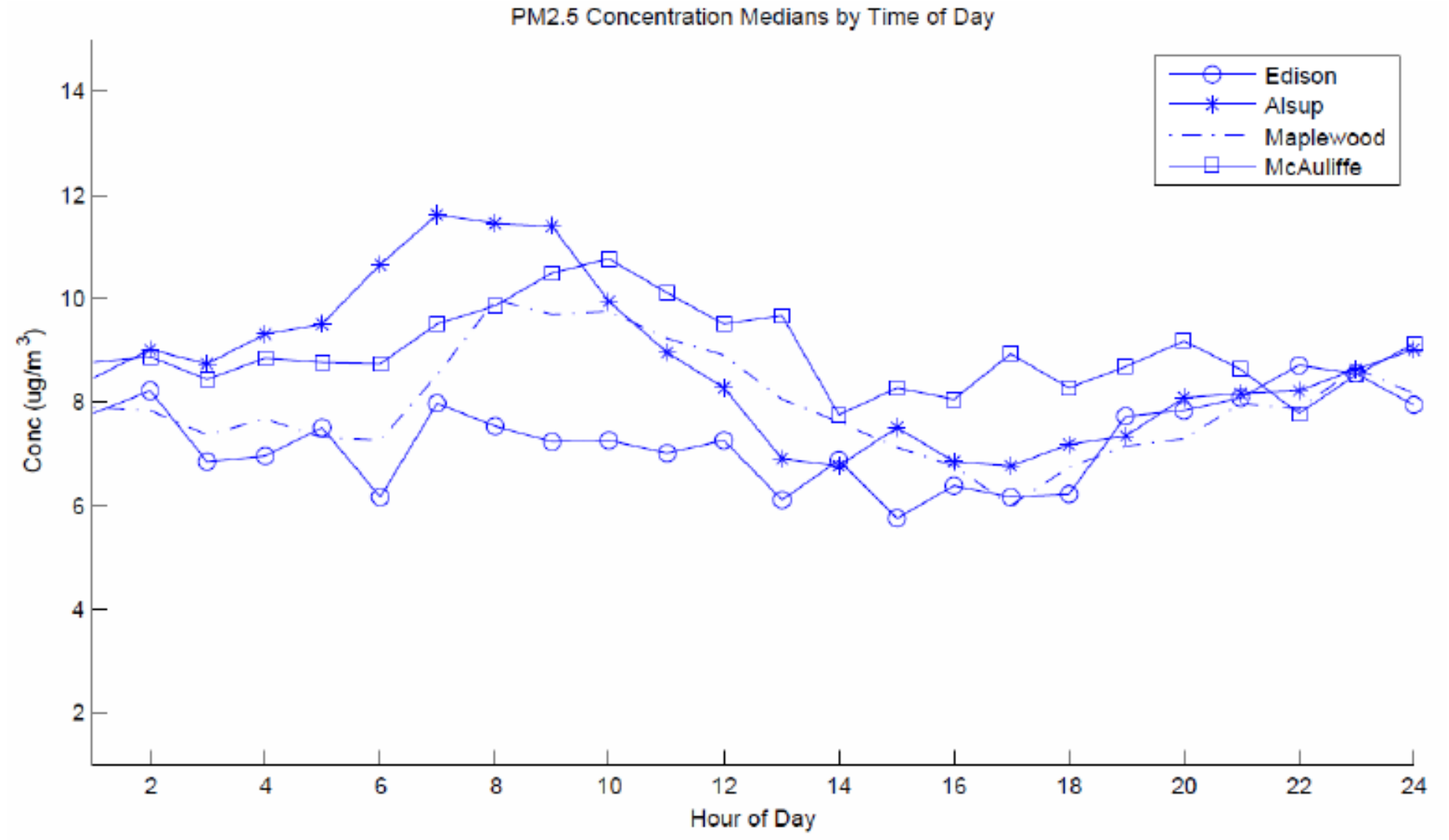
Edison Elementary



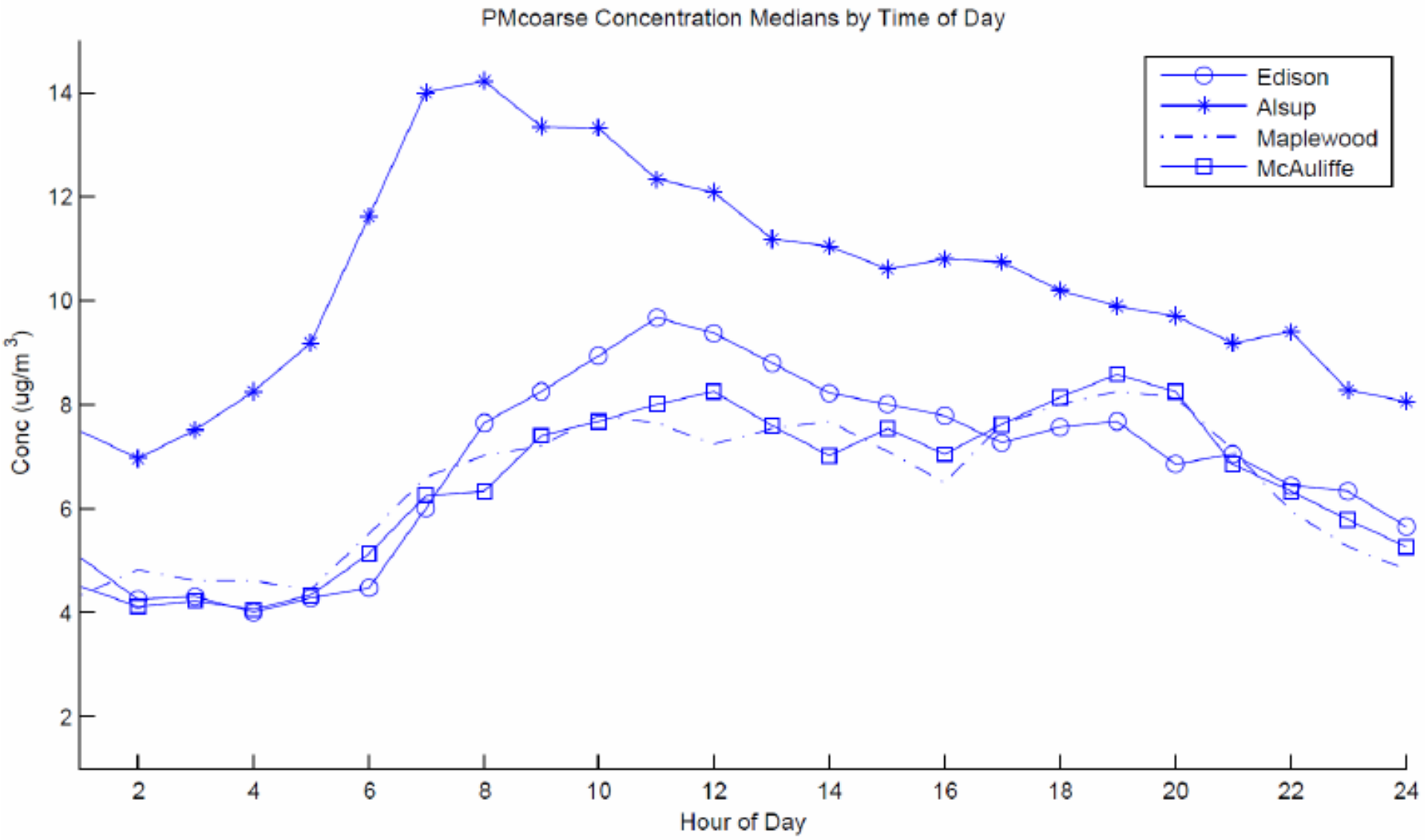
Alsup Elementary



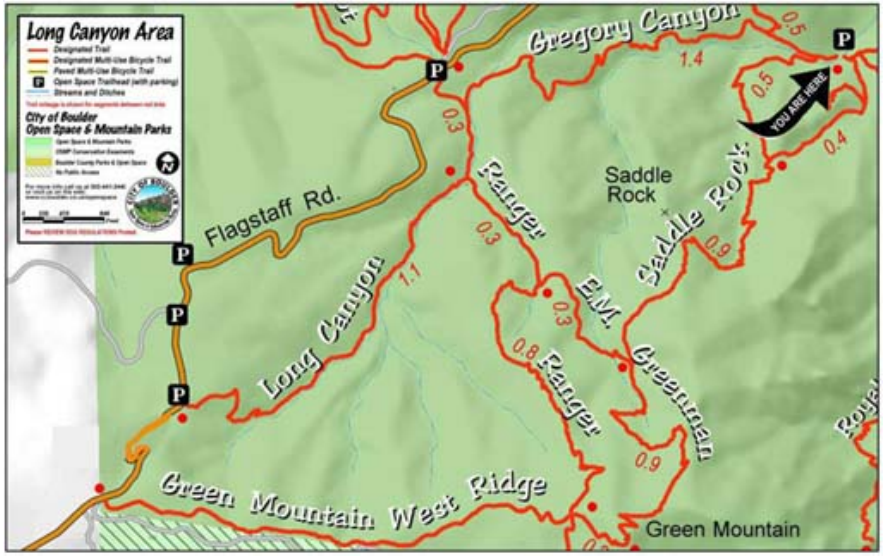
Diurnal Variability, $PM_{2.5}$



Diurnal Variability, $PM_{10-2.5}$



Trail Map



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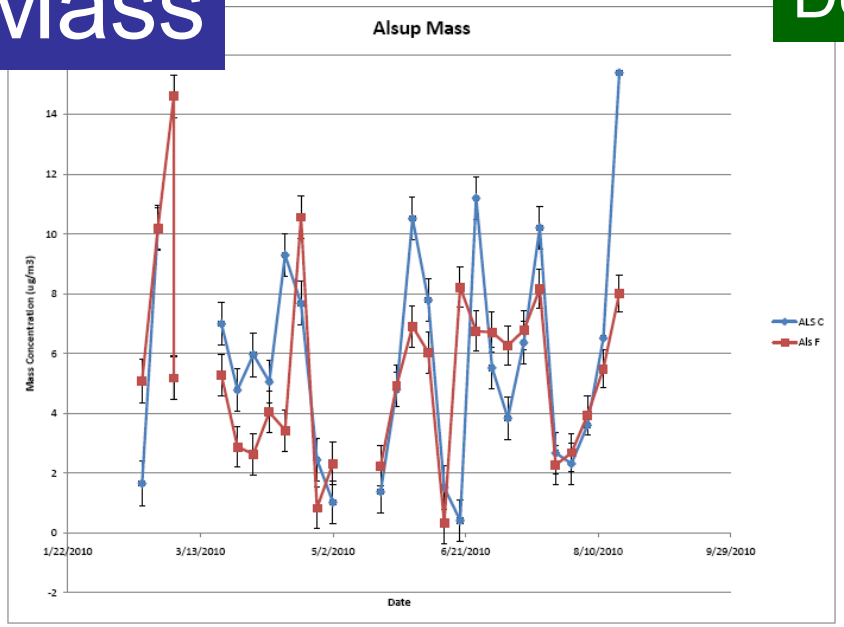
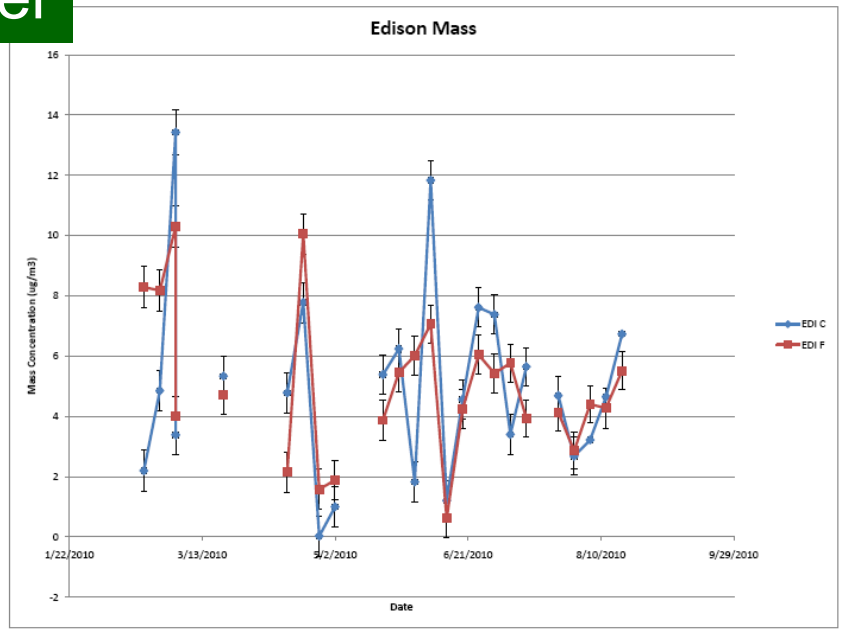
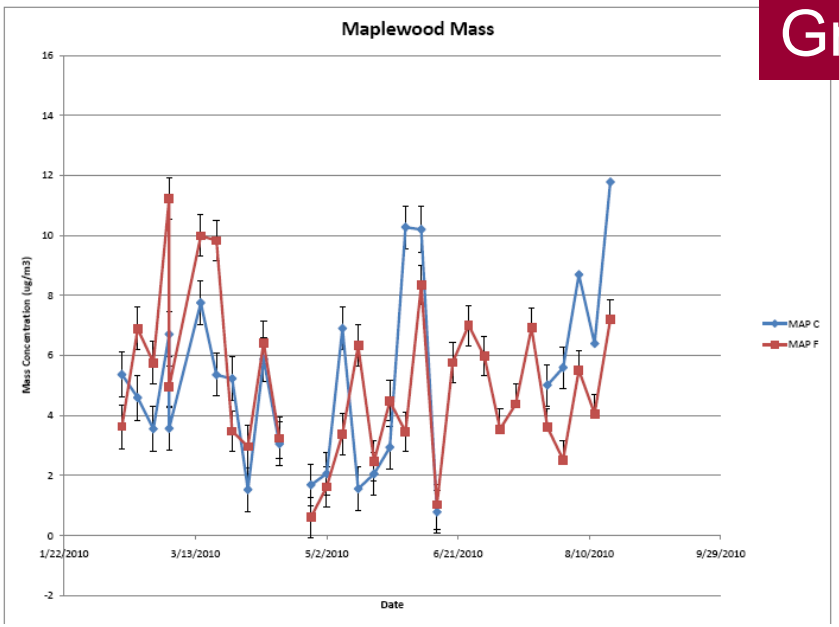
Mass

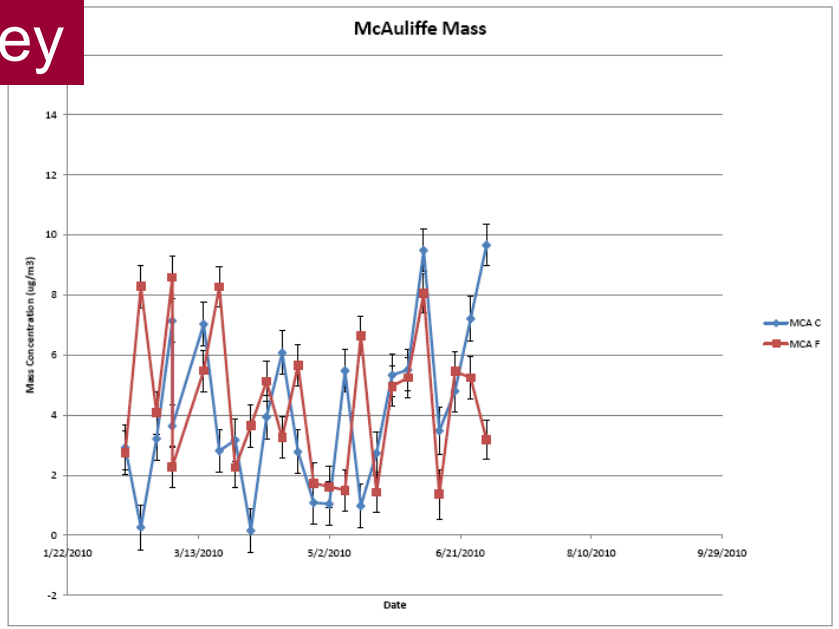
Denver



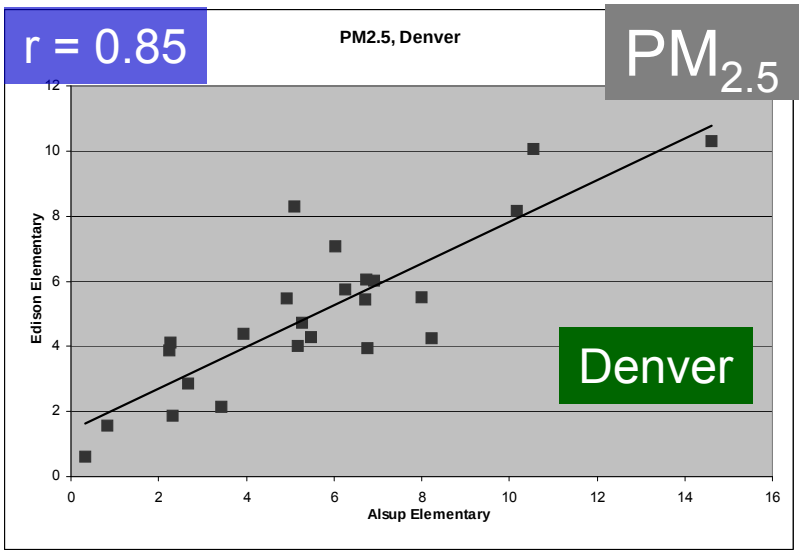


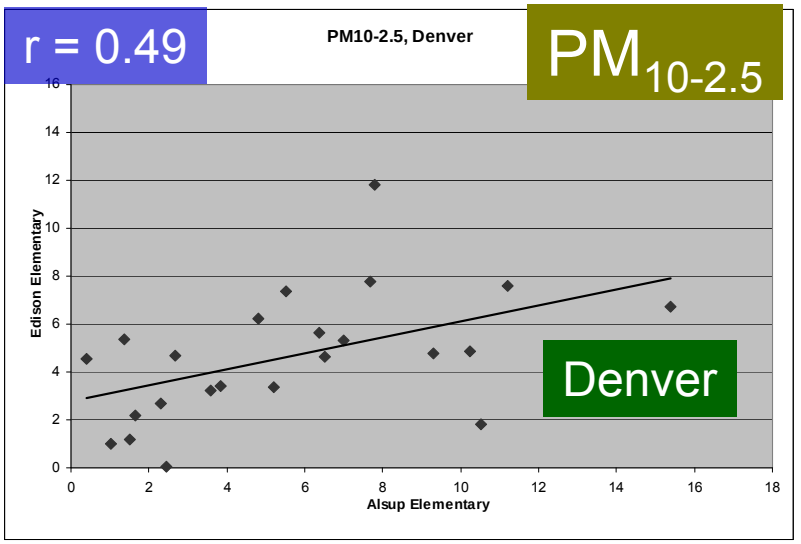
Greeley

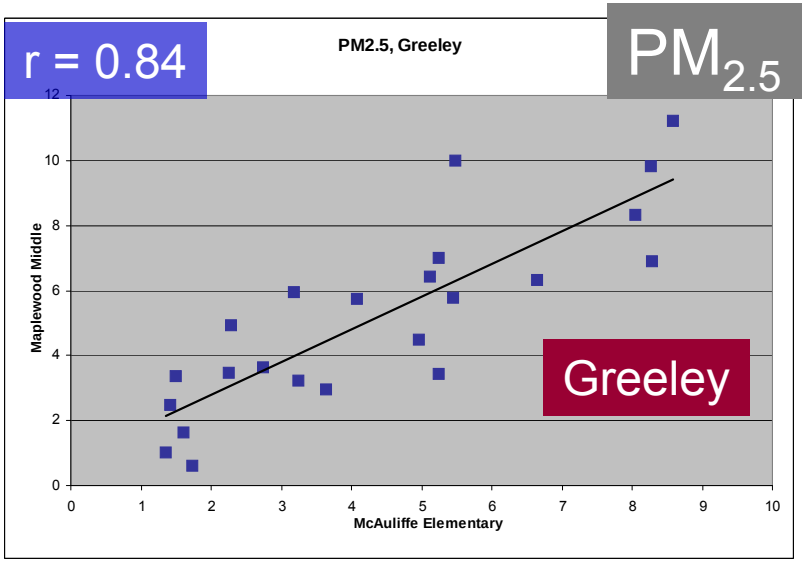


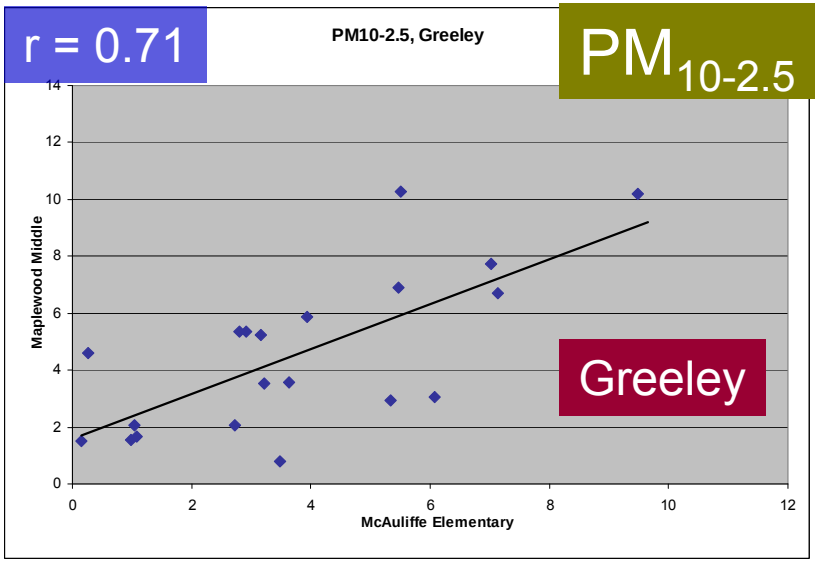


Mass Spatial Variability (daily)

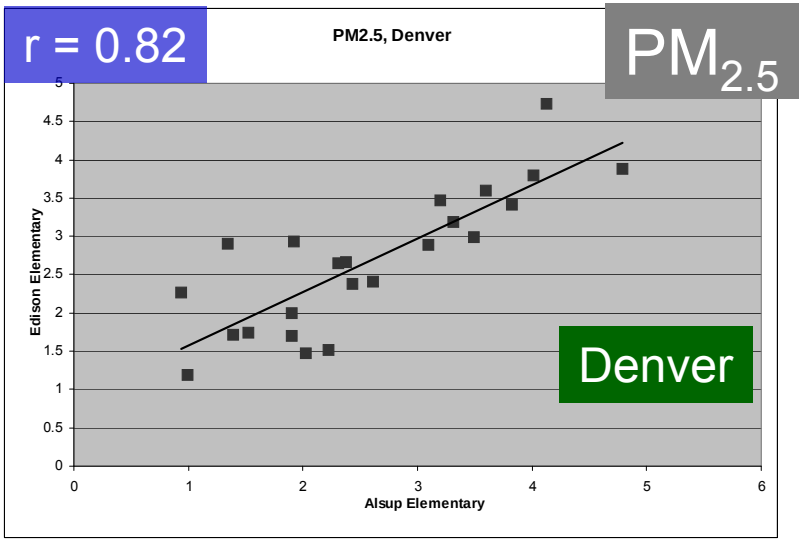


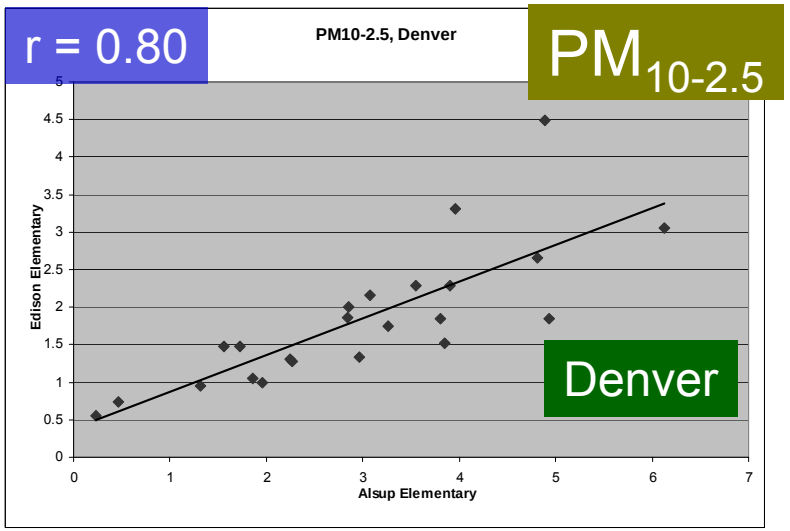


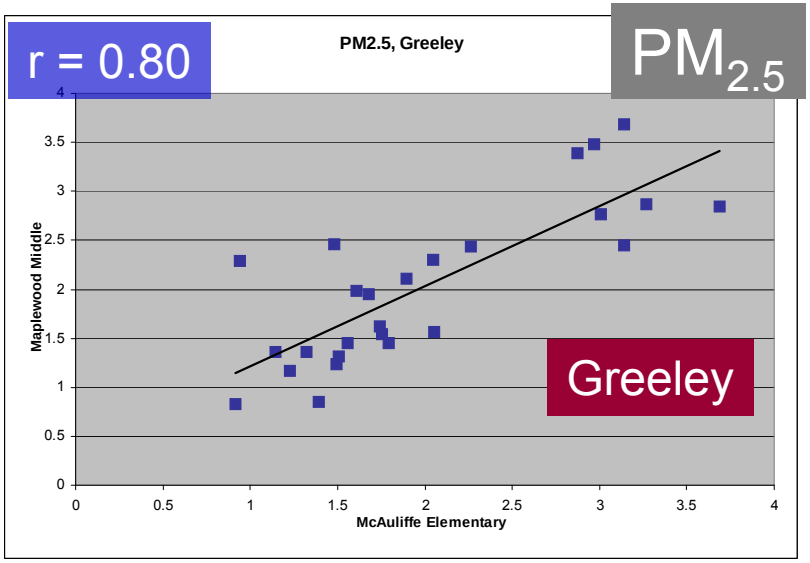


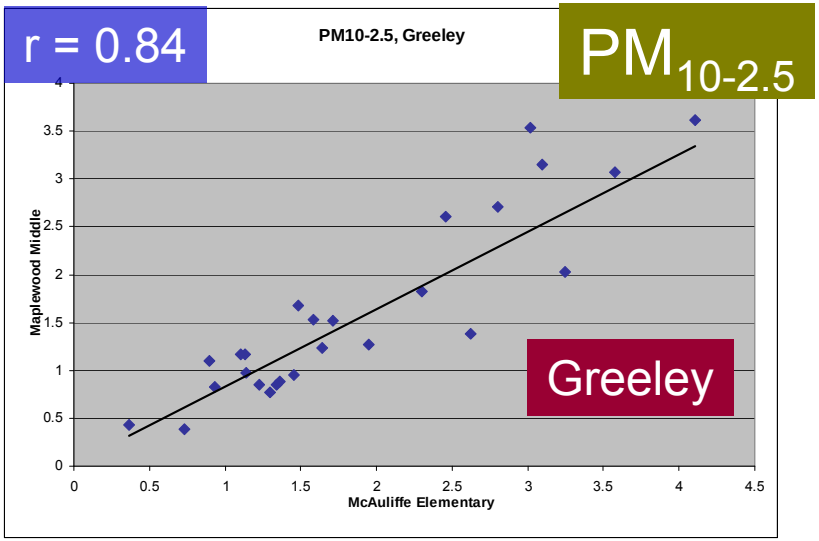


OC Spatial Variability (daily)

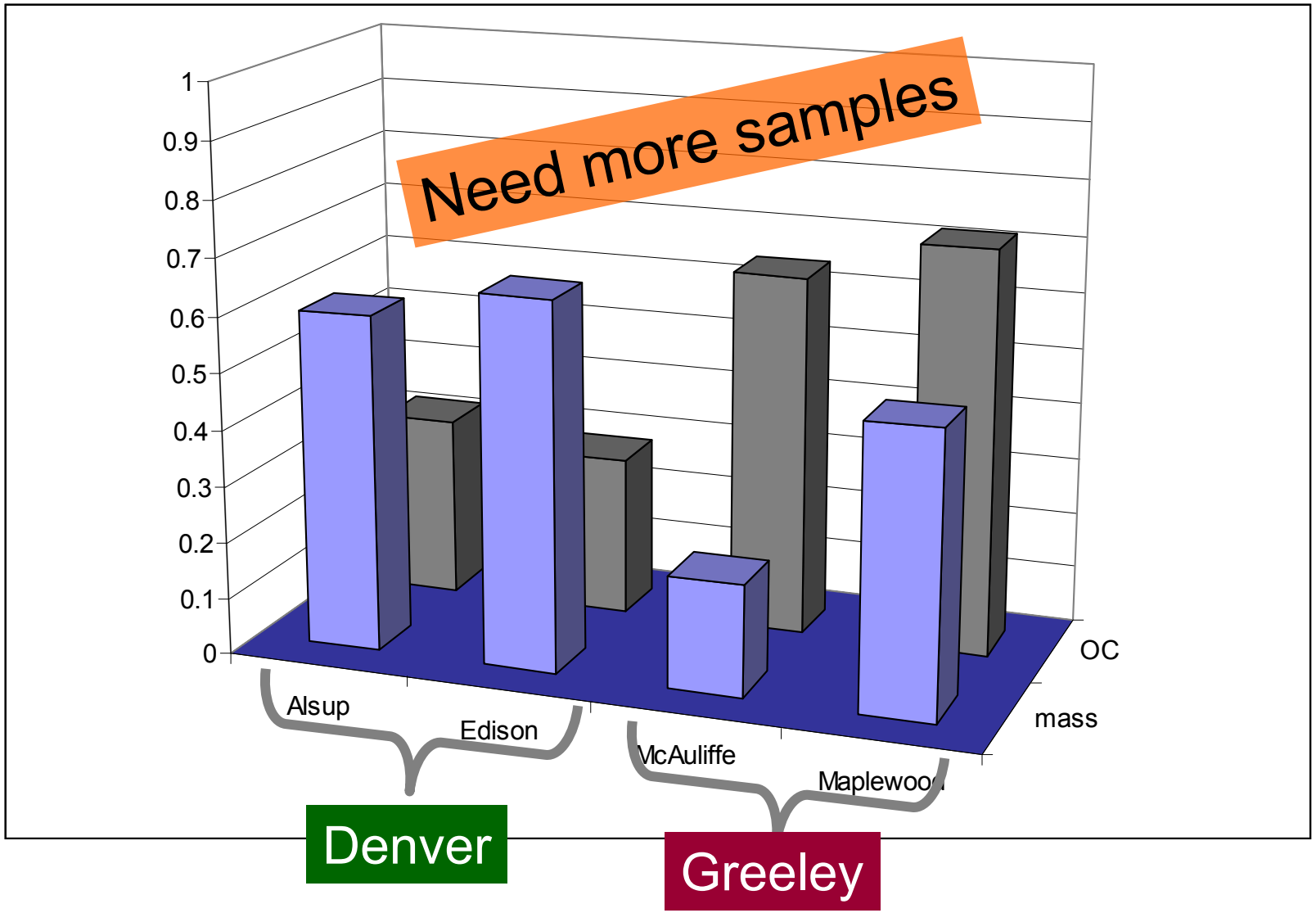




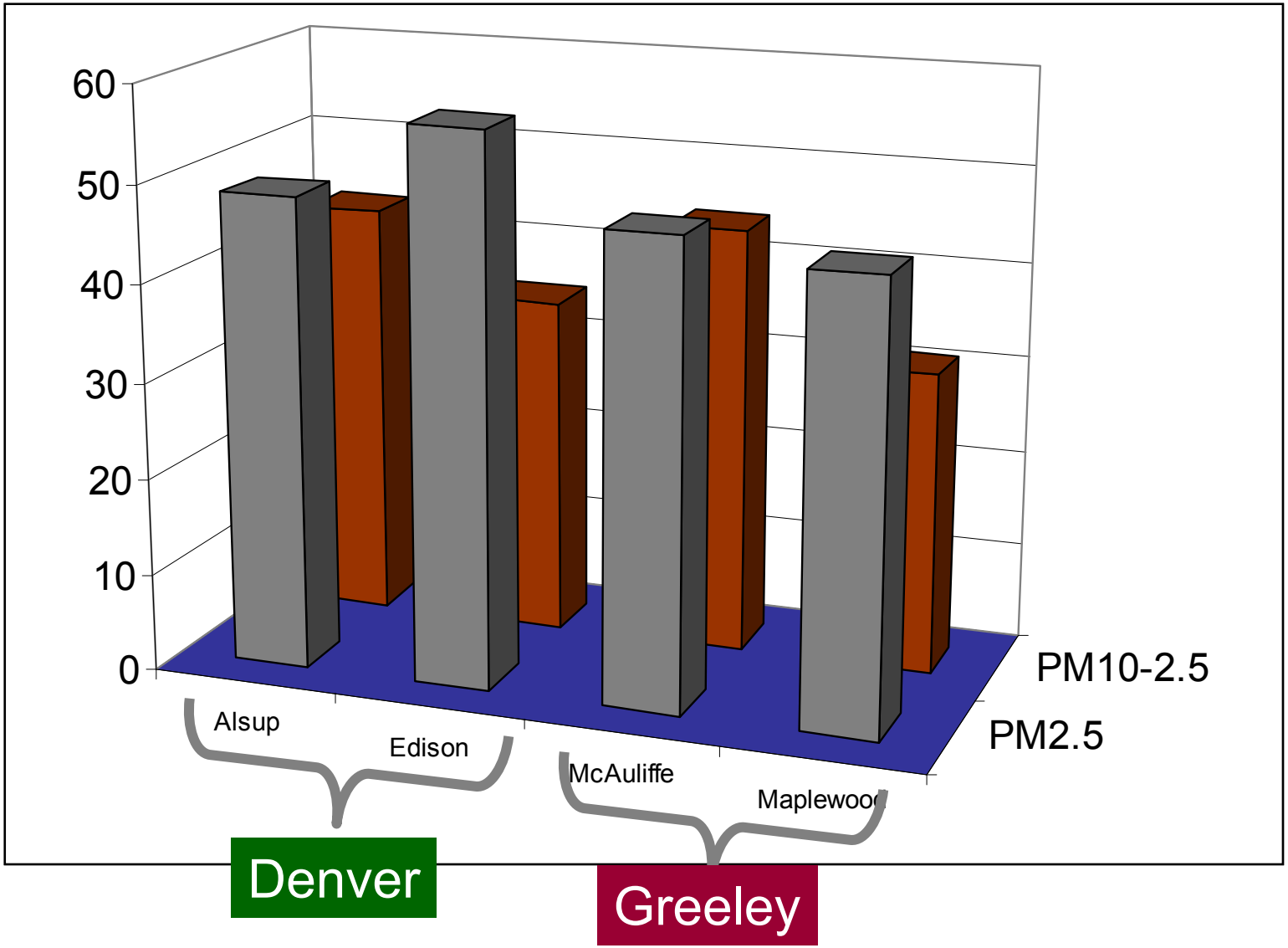




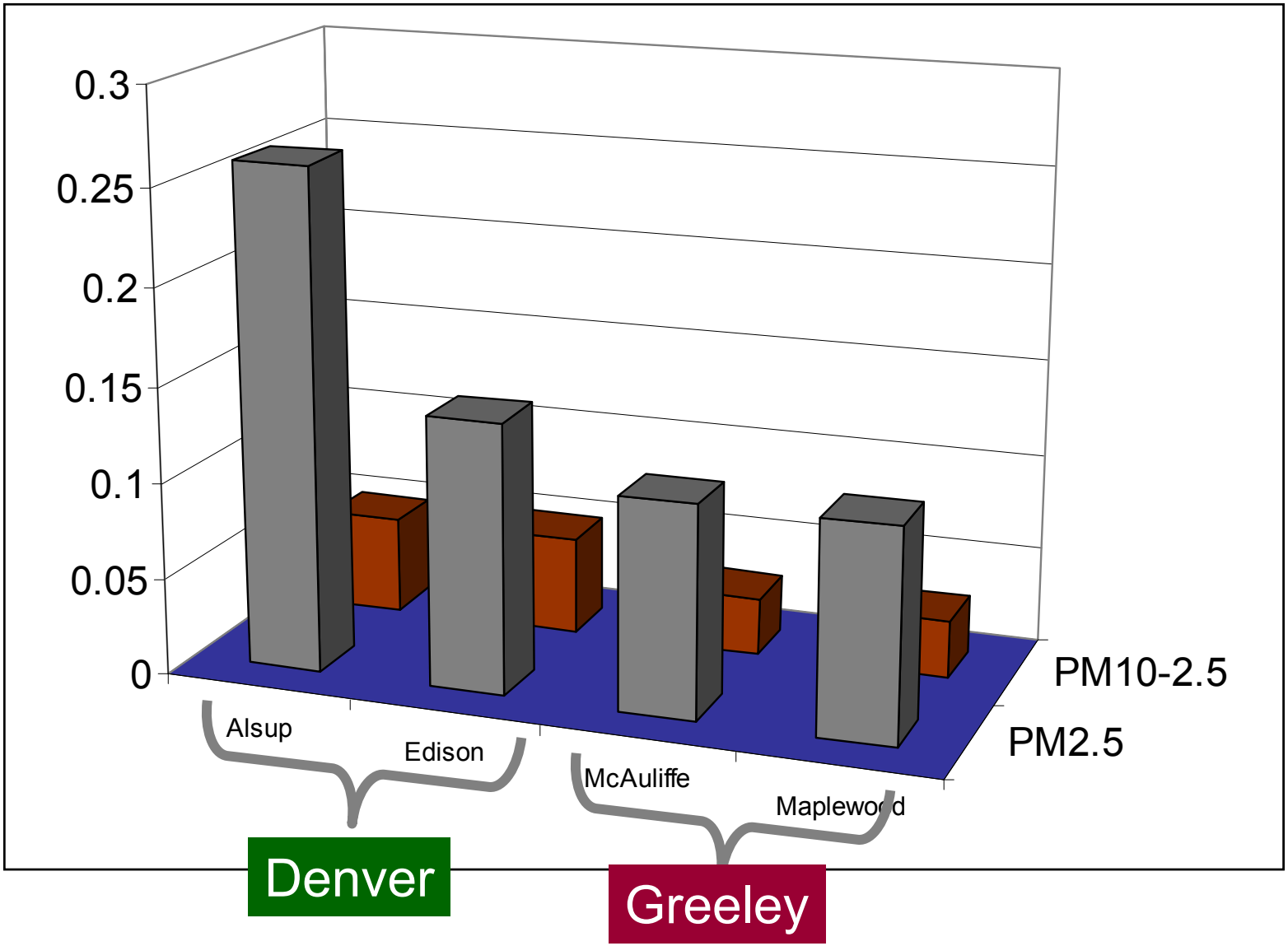
Correlation between sizes



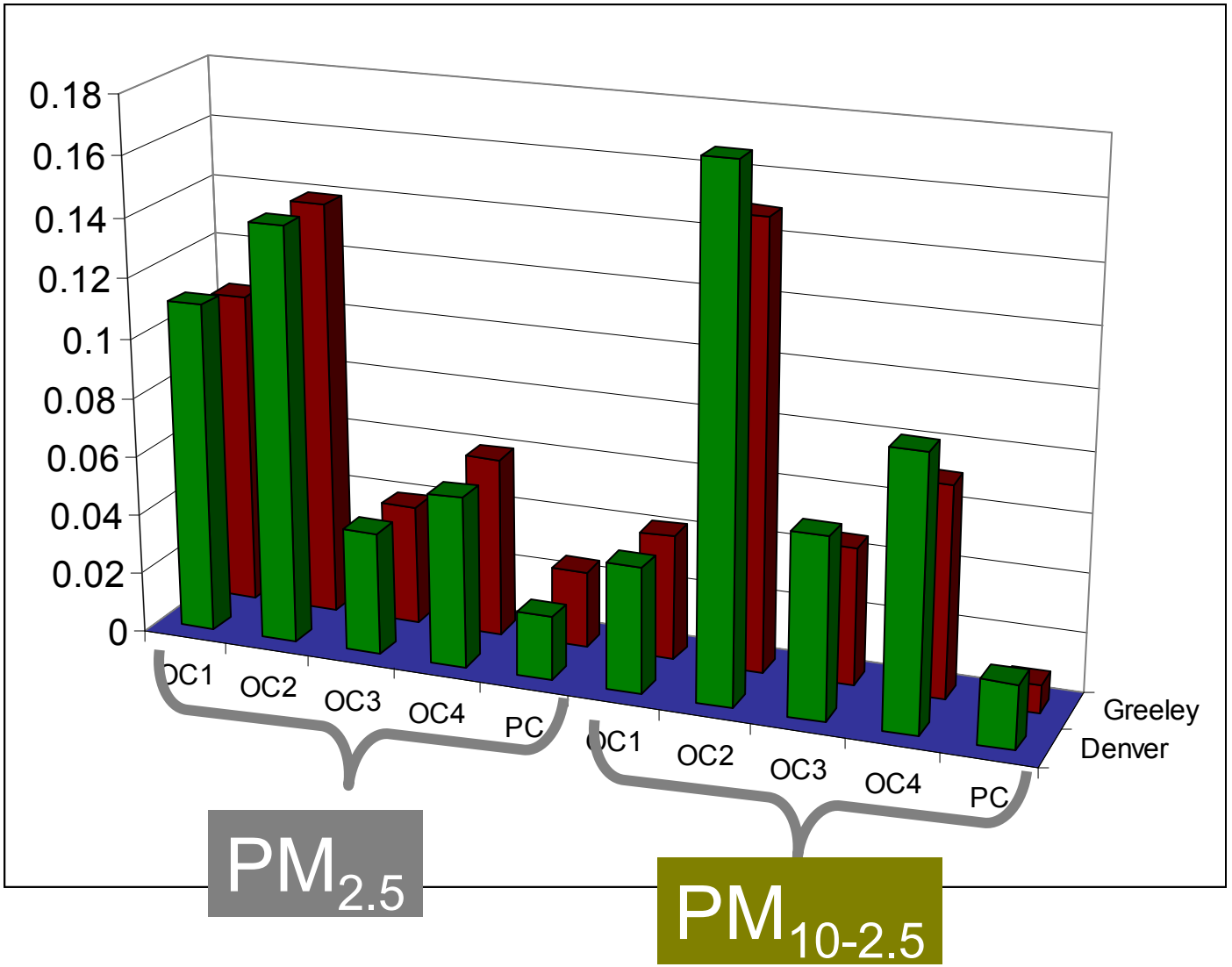
OC as % of Total Mass



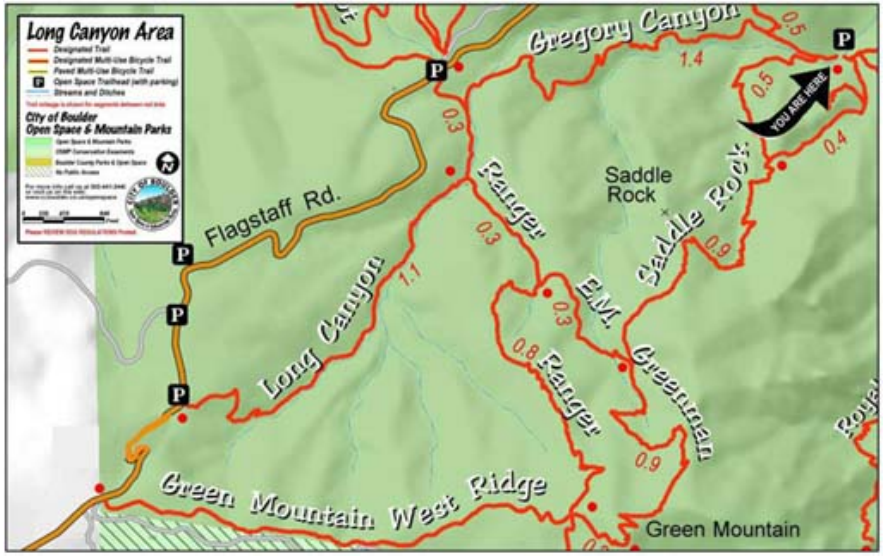
EC/OC


0.3
0.25
0.2
0.15
0.1
0.05
0
Alsup
Edison
McAuliffe
Maplewood
PM10-2.5
PM2.5
Denver
Greeley

OC Volatility



Trail Map



I. What are we doing?

II. Continuous PM measurements

- Challenges (O & M, Data processing)
- Results

III. Filter sampling

- Mass
- Carbonaceous

IV. Near Term Plans

Next 12 months

- More of the same
  - Keep TEOMs running
  - Keep collecting health data
- Finish filter collection
  - Mass, ECOC on all
  - Additional chemical analysis

Why?

Eur Respir J 2005; 26: 309–318
DOI: 10.1183/09031936.05.00001805

REVIEW

Epidemiological evidence of effects of coarse airborne particles on health

B. Brunekreef* and B. Forsberg#

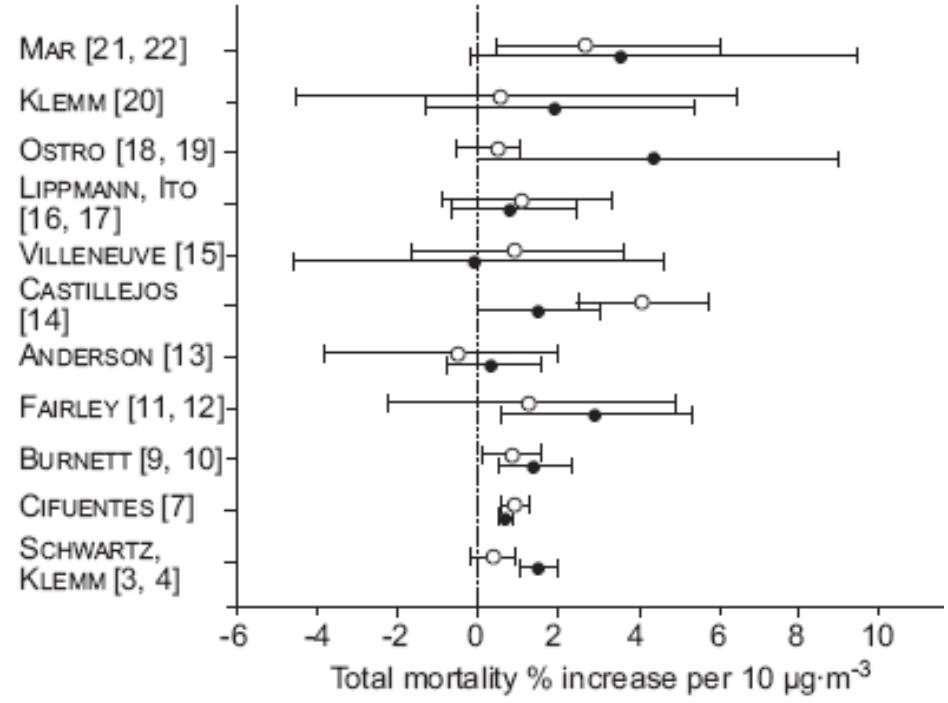


FIGURE 1. Effect of fine (●) and coarse (○) particles on total mortality published time series studies.

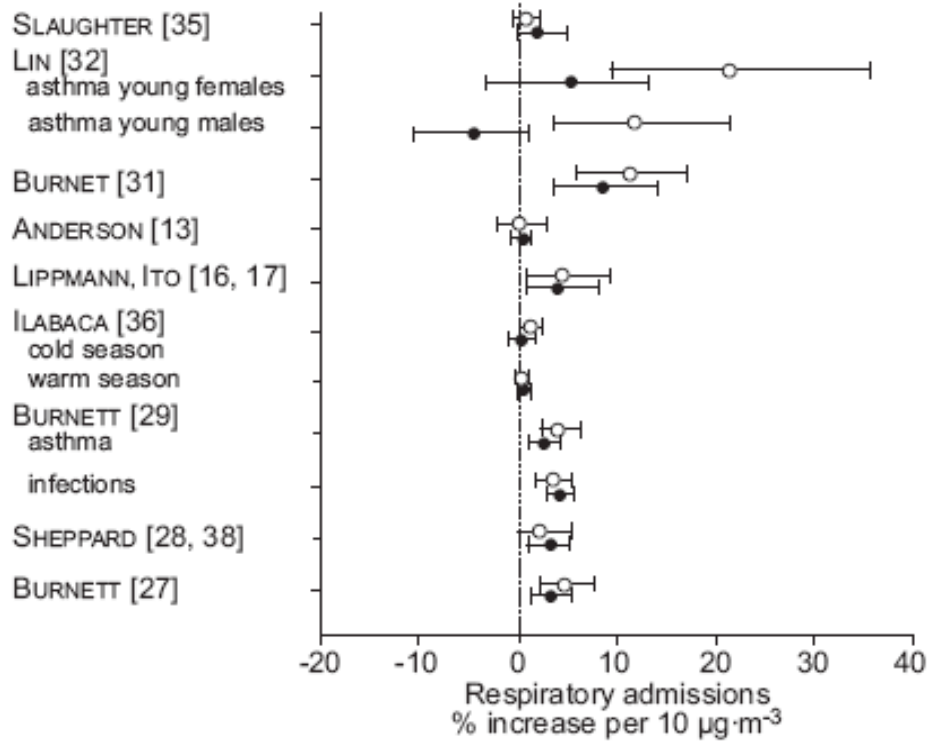


FIGURE 2. Effect of fine (●) and coarse (○) particles on respiratory admissions in published time series studies.

Challenges

- Reproducible effect?
- Urban effect only?
- Spatial heterogeneity?

Power Estimates

Outcome	Denver Number	OR/RR*	Power	Greeley Number	OR/RR*	Power
Arrhythmic events	1,200 event-days	1.05	0.98	600 event-days	1.05	0.89
		1.10	0.99		1.10	0.99
		1.20	0.99		1.20	0.99
Respiratory ED visits	50 visits / day	1.02	0.95	14 visits / day	1.02	0.64
		1.05	0.99		1.05	0.99
		1.10	0.99		1.10	0.99
Cardiovascular ED visits	20 visits / day	1.02	0.62	6 visits /day	1.02	0.32
		1.05	0.99		1.05	0.96
		1.10	0.99		1.10	0.99
Preterm births†	3,000	1.05	0.16	1,200	1.05	0.12
		1.10	0.48		1.10	0.36
		1.50	0.99		1.50	0.99

*OR and RR per 10 $\mu g/m^3$ increase in coarse PM
† Approximately 10% of all births; IUGR will have similar power.